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Line-of-Sight Handbook

by
Carol J. Burge
and Judith H. Lind
Systems Development Department

JANUARY 1977

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R. G. Freeman, III, RAdm., USN Commander
G. L. Hollingsworth Technical Director

FOREWORD

This report documents a study conducted between January and July 1976 at the Naval Weapons Center, China Lake, Calif. The work was conducted under a target acquisition program supported by MIPR RA 46-75, AMCMS Code 675702.12.86300.

The Joint Technical Coordinating Group for Munitions Effectiveness is sponsoring work on air-to-surface target acquisition under its Joint Munitions Effectiveness Manual for the Air-to-Surface Division. Current tasks include the summary of field test data from target acquisition tests, tactics for using air-dropped flares, and the collection of data on terrain and foliage masking (intervisibility).

This report is a handbook for determining line of sight in different types of terrain. It was reviewed for technical accuracy by Ronald A. Erickson of the Naval Weapons Center.

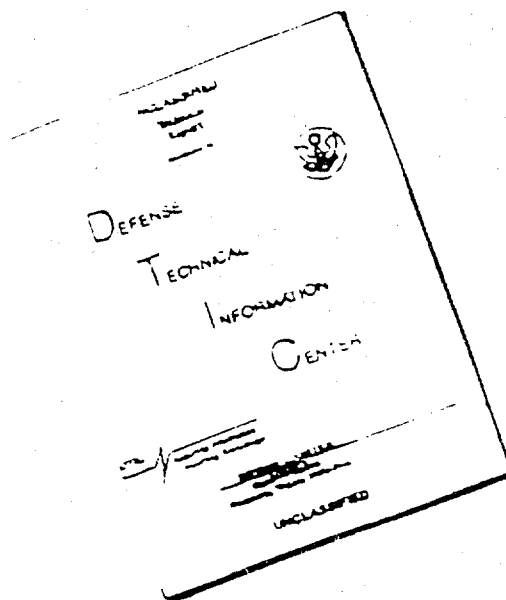
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(U) *Line-of-Sight Handbook*, by Carol J. Burge and Judith H. Lind. China Lake, Calif., Naval Weapons Center, January 1977. 180 pp. (NWC TP 5908, publication UNCLASSIFIED.)

(U) This handbook contains measured line-of-sight (LOS) data for 12 types of terrain and vegetation combinations. The terrain/vegetation types are identified or classified with word descriptions, topographic maps, and aerial and ground photographs. The user can compare these standardized types with the terrain in which he is interested, and select one that matches as closely as possible. The LOS data are provided in the form of graphs that show the probability of a clear LOS as a function of range and altitude, and also the critical altitude (the altitude necessary for a clear LOS) as a function of range.



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INTRODUCTION

A pilot or bombardier/navigator must be able to see his target in order to deliver a weapon. Line of sight (LOS) between aircraft and target is vital. The distance from the target at which a clear line of sight (CLOS) is available often is the limiting factor in weapon delivery. If the target is not seen until late in the attack pass, there is insufficient time for a good launch. If LOS is even temporarily broken late in the attack pass, the target may not be reacquired in time for an accurate hit.

LOS is interrupted most often by terrain, vegetation, man-made objects, and atmospheric conditions such as haze, fog, and smoke. In addition to possible interruption by such objects or conditions, LOS is a function of range and altitude; a shorter range to the target and a higher altitude yield a higher chance of CLOS, as illustrated in Figure 1.

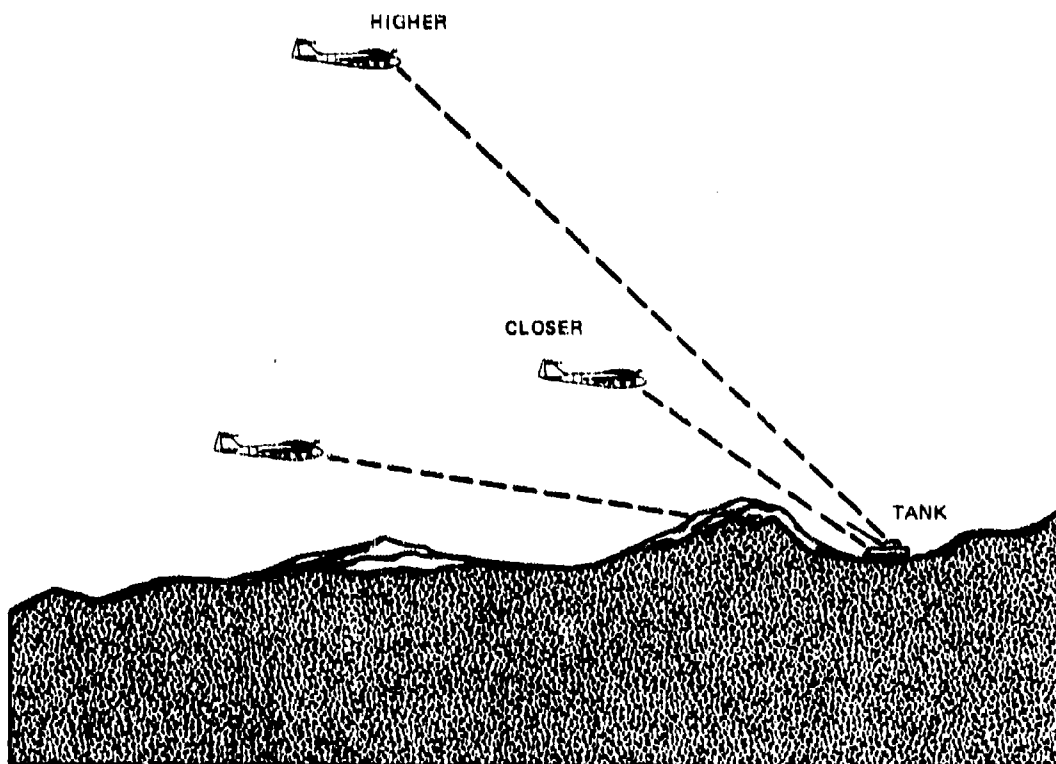


FIGURE 1. Existence of LOS is a Function of Range and Altitude.

The purpose of this handbook is to provide LOS information, as a function of aircraft altitude and of range to the target, for various types of terrain. The data can be used in mission planning to improve the chances of locating targets.

TERRAIN SPECIFICATION

Terrain form is a function both of the shape of the landmass and of vegetation covering that landmass. The terrain form may be described, specified, or classified through:

1. A descriptive name, such as "gently rolling hills with scattered forests" (accompanied, when needed, by narrative description).
2. Topographic maps.
3. Aerial and ground photographs.

All three kinds of terrain/vegetation specifications are included in this report for the first eight terrain types considered (A through H), for which data were collected in the United States. These are arranged in order of increasing masking, as follows:

<u>Terrain type</u>	<u>Vegetation type</u>
A. Farmland, fairly flat	Thick forests in distance
B. Desert, fairly smooth	Scattered bushes
C. Farmland, rolling	Thick forests, close
D. Desert, moderately rough Hills, rolling	Scattered bushes
E. Farmland, flat	Thick forests, close
F. Hills, gently rolling	Scattered trees
G. Desert, rough	Scattered bushes
H. Hills, sharply rolling	Thickly scattered trees

It should be noted that terrain type D includes both desert and hill measurements. Results were so similar that these two forms of terrain were considered as the same terrain/vegetation type for this report.

The final four kinds of terrain considered in this report (types I, J, K, and L) are described as "typical British countryside." Information for these was collected by the British Royal Air Force. No maps or photographs are available.

No attempt has been made to include all possible terrain/vegetation types in this handbook. Among those missing are such maximum masking conditions as jungle or forest where the possibility of CLOS is essentially zero. Flat, open plains and large bodies of water also are omitted since LOS there would be unlimited and unlikely to be a factor in weapon delivery.

CRITICAL ALTITUDE

Critical altitude is the altitude at which an observer must be in order to see a target from a given ground range. If an observer is as high as or higher than the critical altitude, he will have a clear LOS to the target. Critical altitude depends on terrain type and range; the farther one is from a target, the higher one has to be to see it.

If, as in Figure 2, a circle is drawn around a target at a given range from it and the critical altitude measured at many points on the circle, the average critical altitude for that range in that kind of terrain can be computed. This average is the altitude from which one might expect to have a CLOS about 50% of the time. A higher probability level can be selected by including more (and higher) critical altitudes of the sample. The graphs of critical altitude versus range presented in this report show a 50% curve and a 97.5% curve.

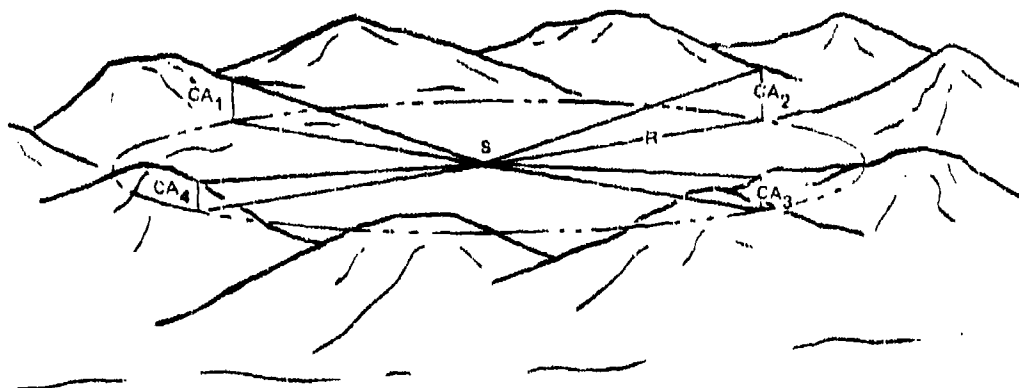


FIGURE 2. Mean Critical Altitude at Range R is the Average of All the Critical Altitudes, CA.

PROBABILITY OF LOS

By comparing the altitude with critical altitude, the probability that LOS will exist has been calculated for each of the terrain/vegetation types considered. This information is provided in the form of two sets of curves that plot the probability of CLOS as a function of altitude and of range, as shown in Figures 3a and 3b.

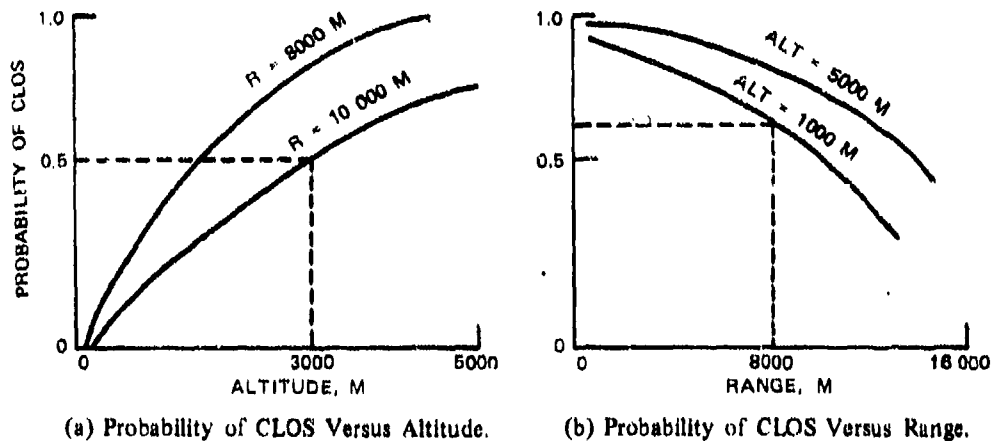


FIGURE 3. LOS as a Function of Altitude and of Range.

For choosing an altitude at which to fly, the curves like those in Figure 3a will be the most helpful; i.e., at a range of 10 000 m, one must be at an altitude of at least 3000 m for the probability of CLOS to be 0.5. If one is primarily interested in how far from the target a CLOS can be expected, the set of probability versus range curves (such as Figure 3b) should be used. For example, at an altitude of 1000 m, there is a probability of 0.65 of having a CLOS at a range of 8000 m. All altitudes given are altitude above the target.

DATA COLLECTION

Field measurements were made in the Mojave Desert and Tehachapi Mountain areas of California, and in farmland-type terrain near Ft. Rucker, Ala., for terrain/vegetation types A through H. Precise surveying equipment was used to measure the range and angle to masking objects such as hills and significant vegetation. Man-made features and atmospheric conditions such as haze and smoke were not included as masking objects. A later report will explain in detail how measurements were made and computations were performed.

Terrain types I, J, K, and L were studied by the British Royal Air Force during target acquisition trials in support of the V/STOL Harrier.¹ Because the British data consist only of the angle to the skyline and do not include any ranges, they are not as accurate (or useful) as other data in this report. Measurements were collected in "typical British countryside" for 60 sites. For this report, these have been divided into four groups on the basis of the similarity of the probability of LOS curves.

USE OF HANDBOOK

Users of this handbook should read the terrain descriptions and look at the photos and maps, comparing these with the appearance and description of the areas in which they are interested. When the closest match possible has been decided upon, a terrain/vegetation type can be assigned to the area of interest. LOS curves for that terrain/vegetation type then can be studied to determine the probability of being able to see the target at various altitudes and ranges.

There are five LOS graphs provided for each of the eight U.S. types of terrain and vegetation. The first graph plots critical altitude versus range for two probability levels. Next, there are four probability of LOS graphs. The first two supply probability of LOS as a function of altitude and range when altitudes are 1000 m or less. The second two provide the same information for altitudes up to 5000 m.

¹ Gilbert Haugh, "Review of Target Acquisition Data From RAF Tactical Trials," presented at the Technical Cooperation Program Panel W-6, 2nd Technical Session Agenda, San Clemente, Calif., May 1974.

LINE-OF-SITE DATA

DATA COLLECTED FROM UNITED STATES

A. Fairly Flat Farmland With Distant Forests (see Figures 4 through 8)

"Fairly flat farmland with distant forests" sites are flat fields in naturally forested land, where quite extensive areas have been cleared for farming.

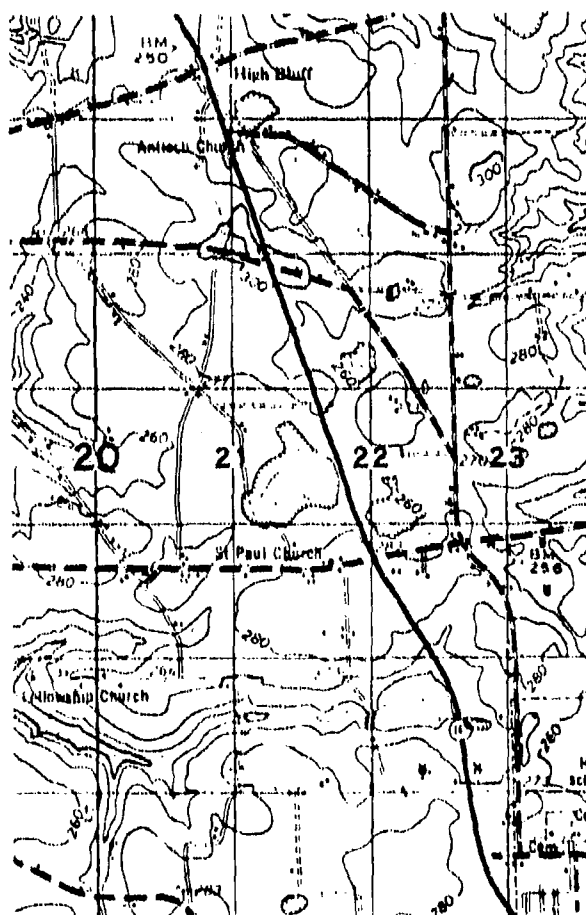


FIGURE 4. Topographic Map of Fairly Flat Farmland. Scale is 1:50,000; contour interval is 20 ft.



(a) Aerial view.



(b) Ground view.

FIGURE 5. Photographs of Fairly Flat Farmland. Distant Forests.

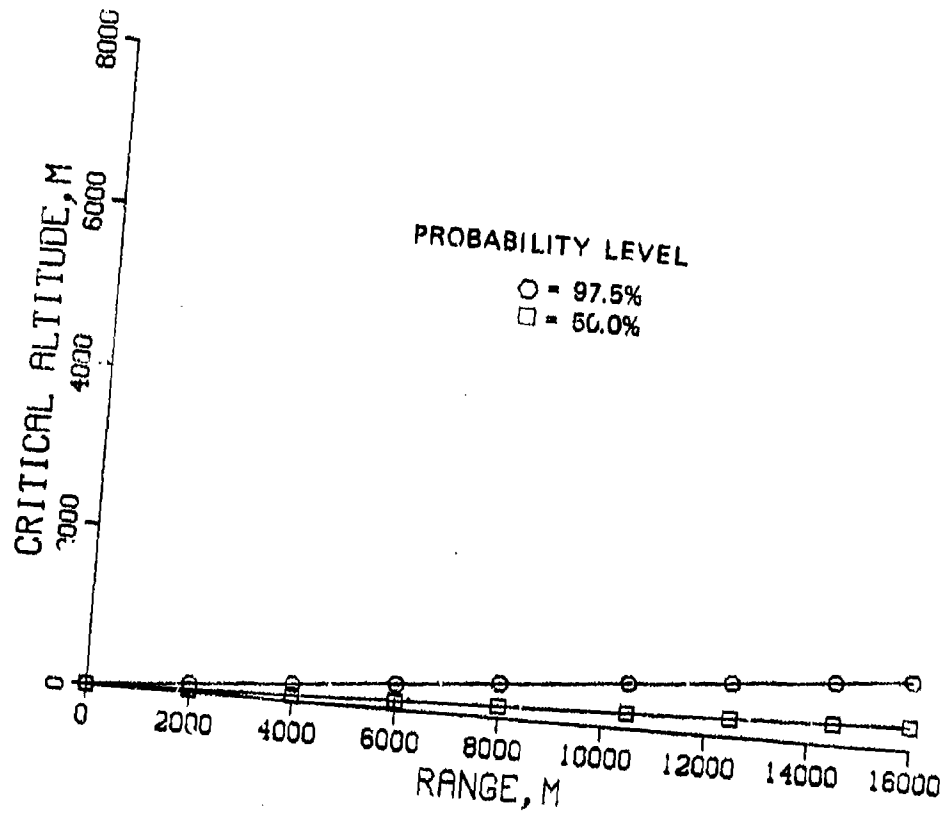


FIGURE 6. Critical Altitude as a Function of Range in Fairly Flat Farmland With Forests in Distance.

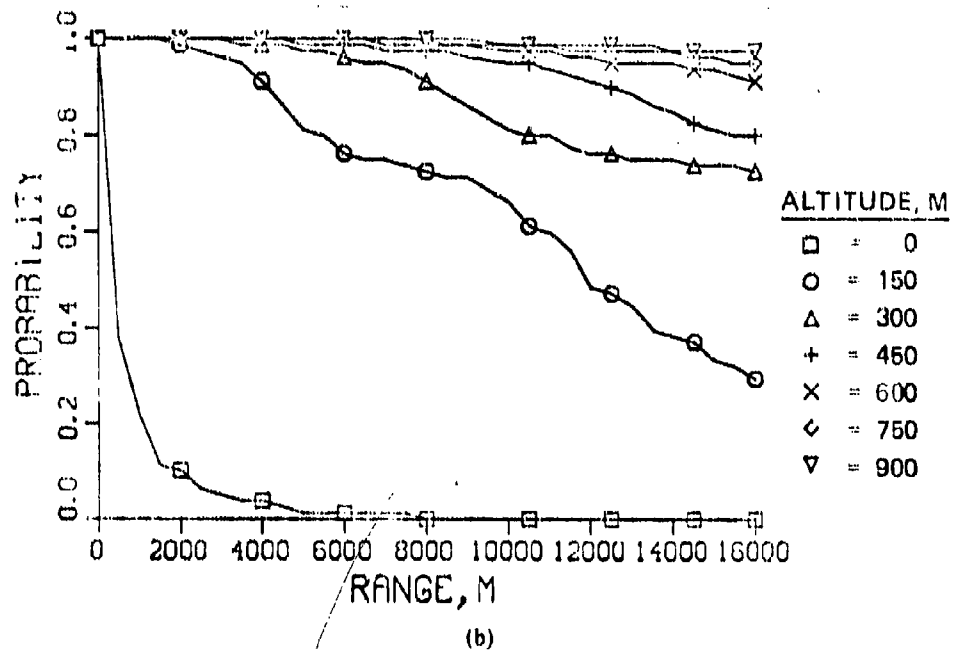
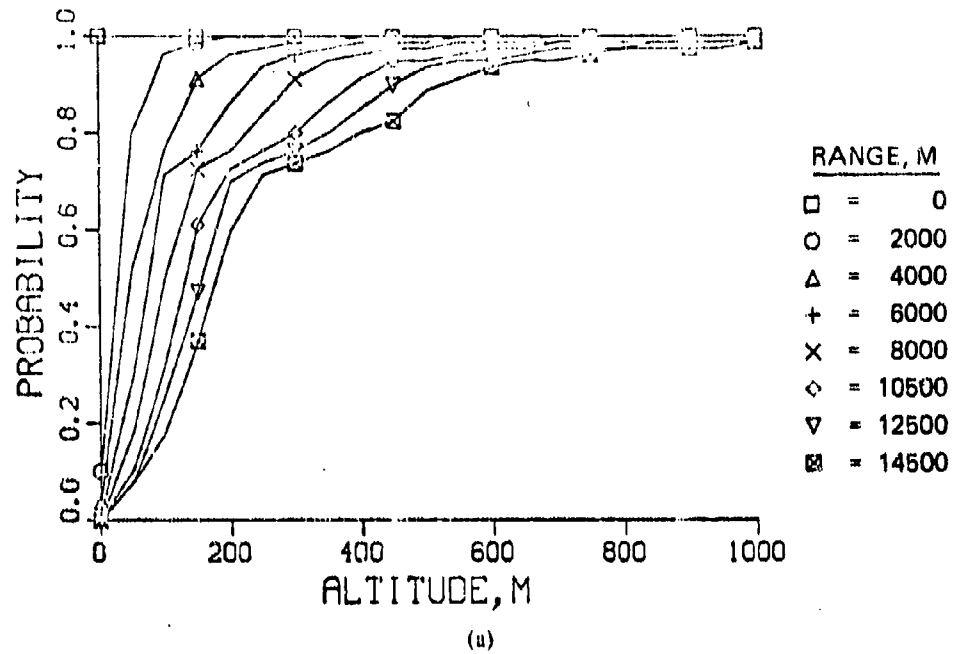
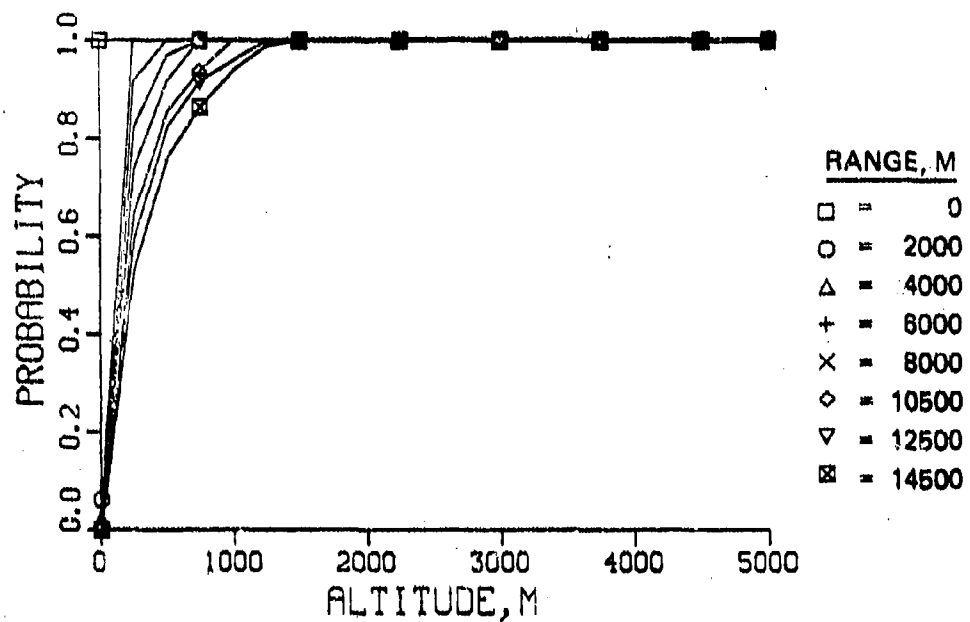
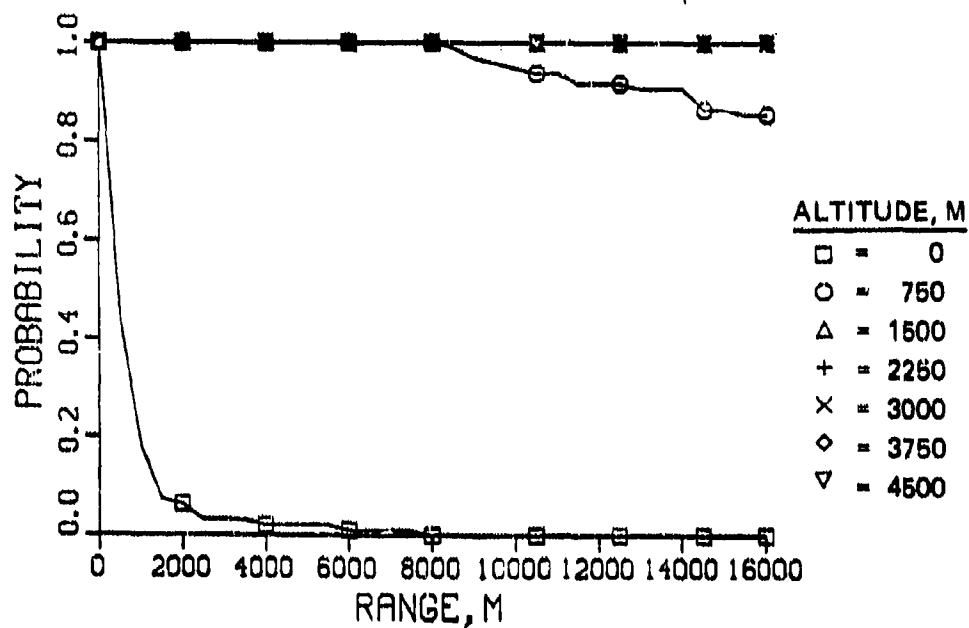


FIGURE 7. Average Probability of LOS in Fairly Flat Farmland With Forests in Distance as a Function of (a) Altitude up to 1000 m, and (b) Range.



(a)



(b)

FIGURE 8. Average Probability of LOS in Fairly Flat Farmland With Forests in Distance as a Function of (a) Altitude up to 5000 m, and (b) Range.

B. Fairly Smooth Desert (see Figures 9 through 13)

Fairly smooth desert terrain is characterized by low, gentle undulations with a few abrupt low hills or rock outcroppings. Vegetation is mostly creosote bushes less than 6 feet tall and usually growing several feet apart.

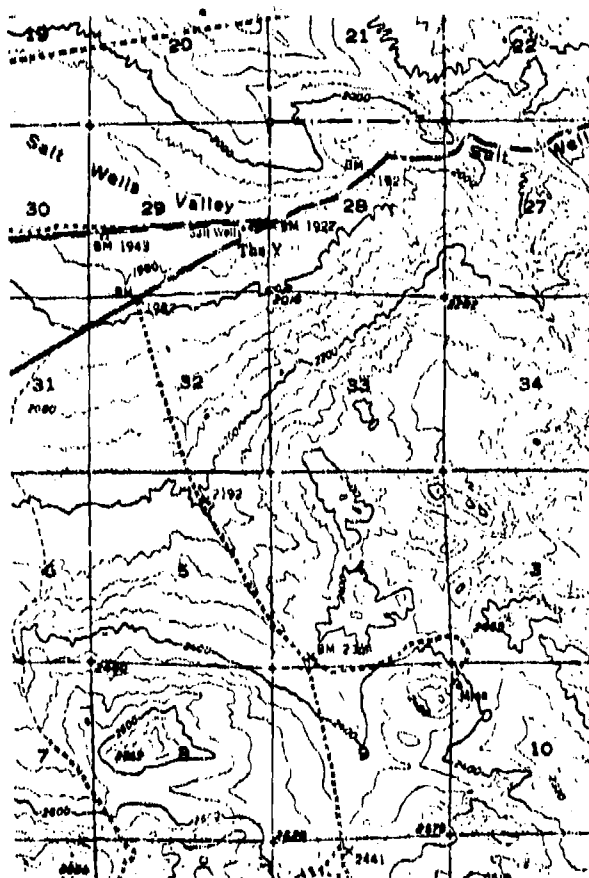
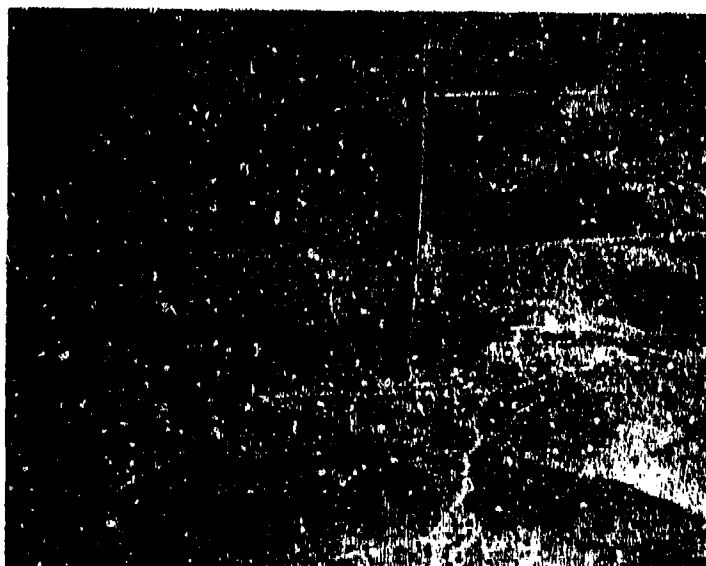
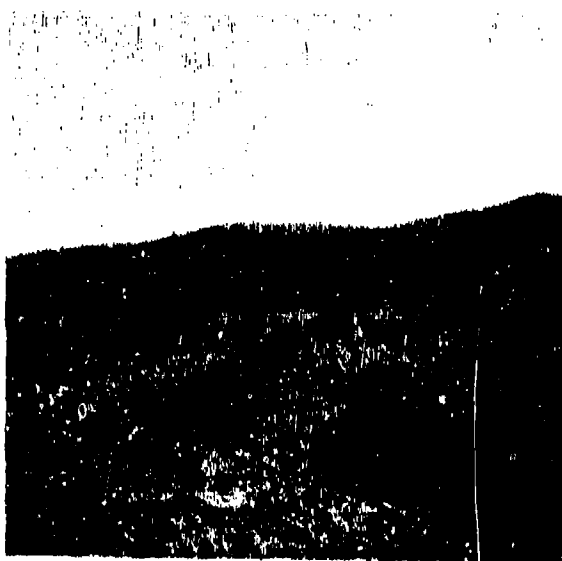


FIGURE 9. Topographic Map of Fairly Smooth Desert Terrain. Scale is 1:62,500; contour interval is 40 ft.

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(a) Aerial view.



(b) Ground view.

FIGURE 10. Photographs of Fairly Smooth Desert Terrain.

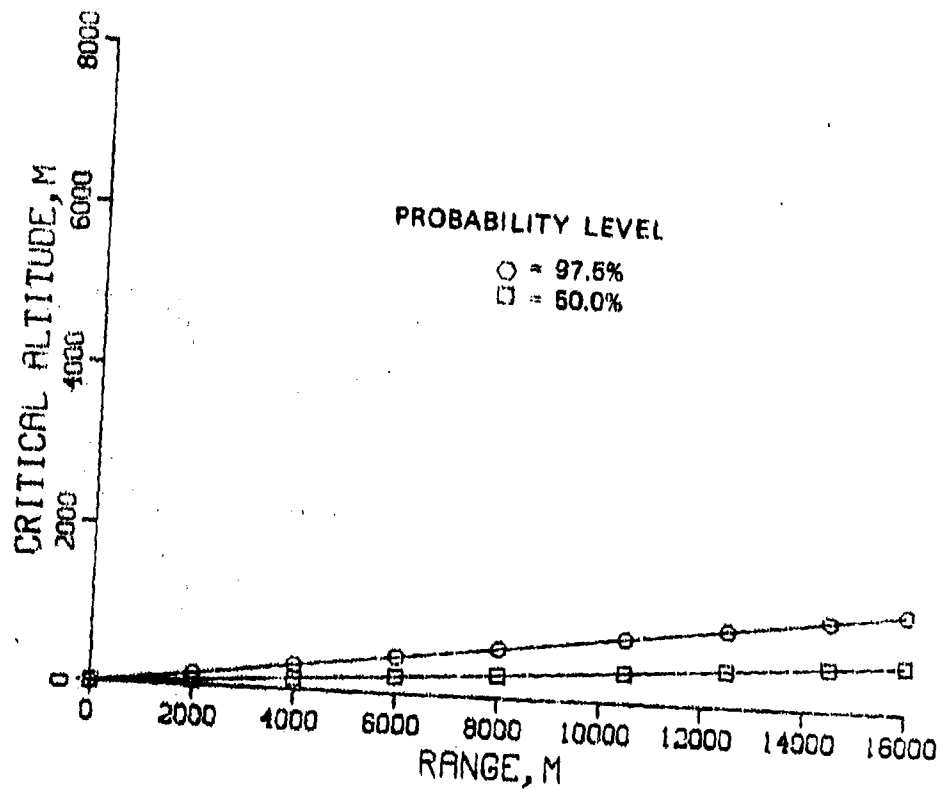
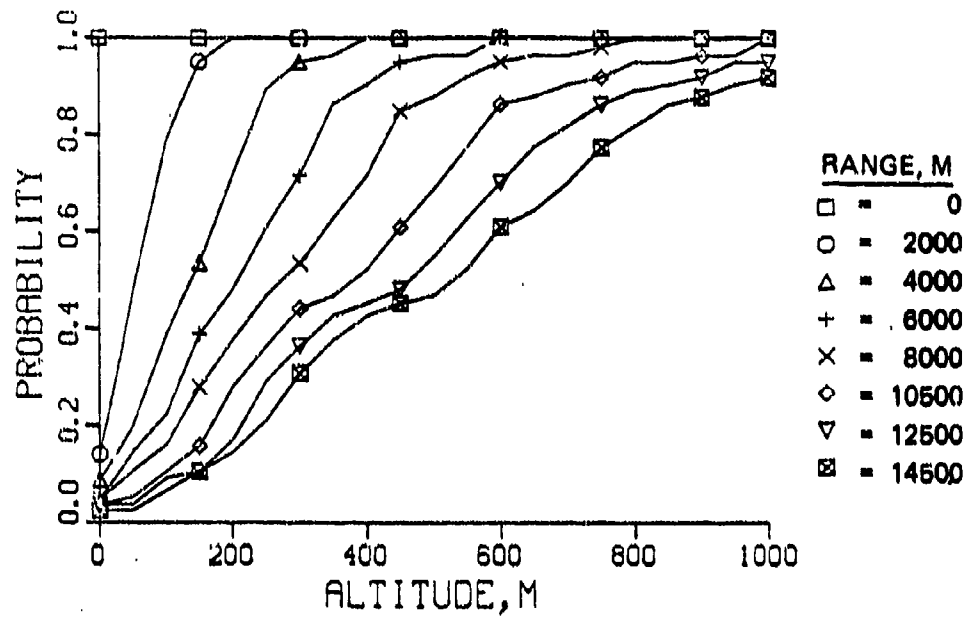
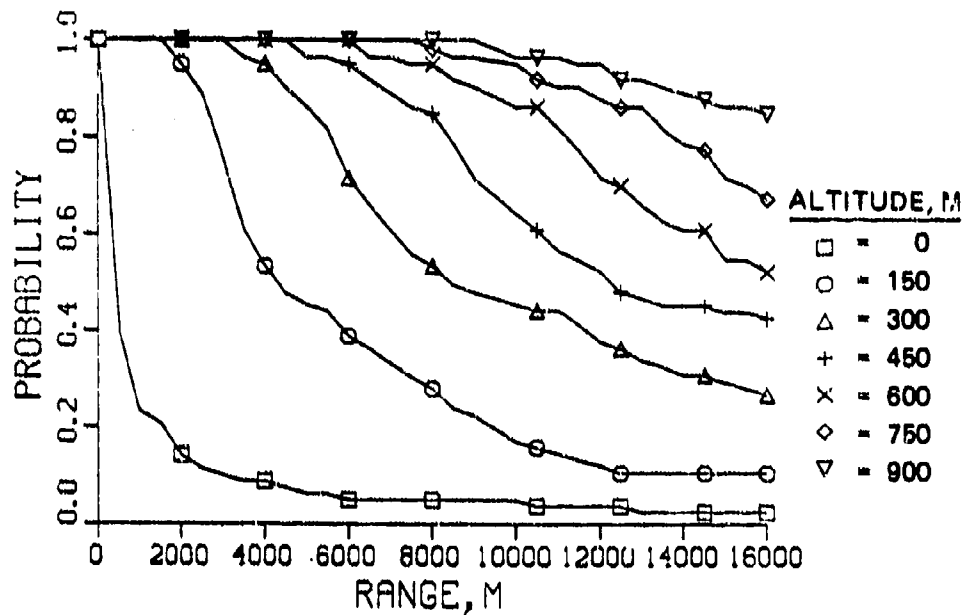


FIGURE 11. Critical Altitude as a Function of Range in Fairly Smooth Desert.



(a)



(b)

FIGURE 12. Average Probability of LOS in Fairly Smooth Desert as a Function of (a) Altitude up to 1000 m, and (b) Range.

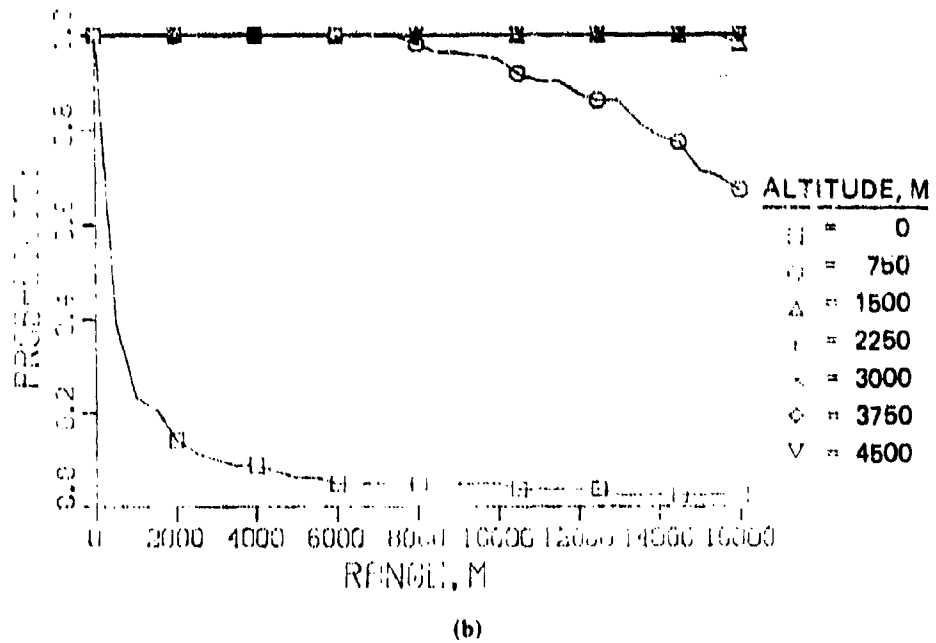
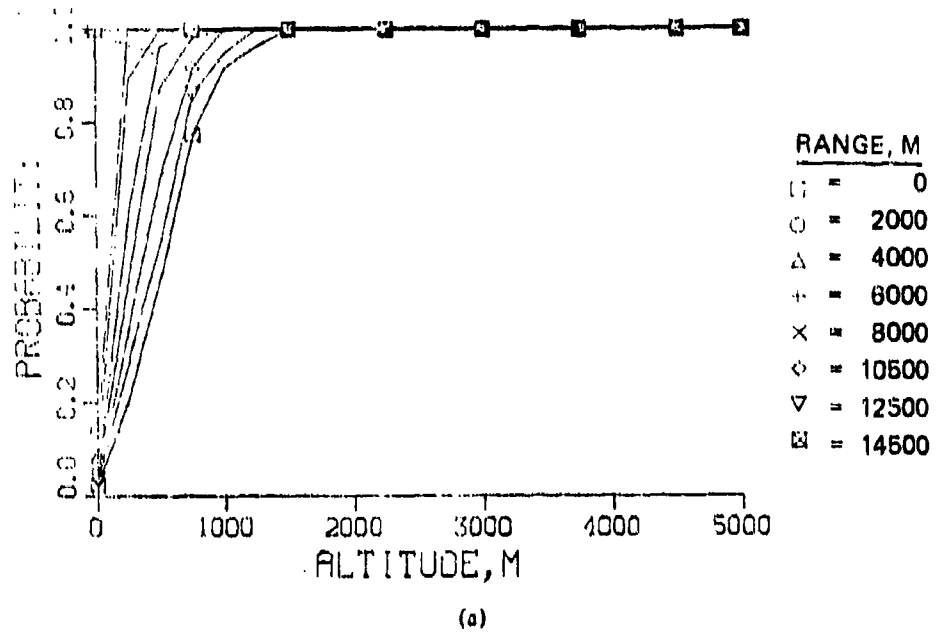


FIGURE 13. Average Probability of LOS in Fairly Smooth Desert as a Function of (a) Altitude up to 5000 m, and (b) Range.

C. Gently Rolling Farmland With Close Forests (see Figures 14 through 18)

This type of terrain is characterized by relatively small fields cleared in forested, gently rolling land.

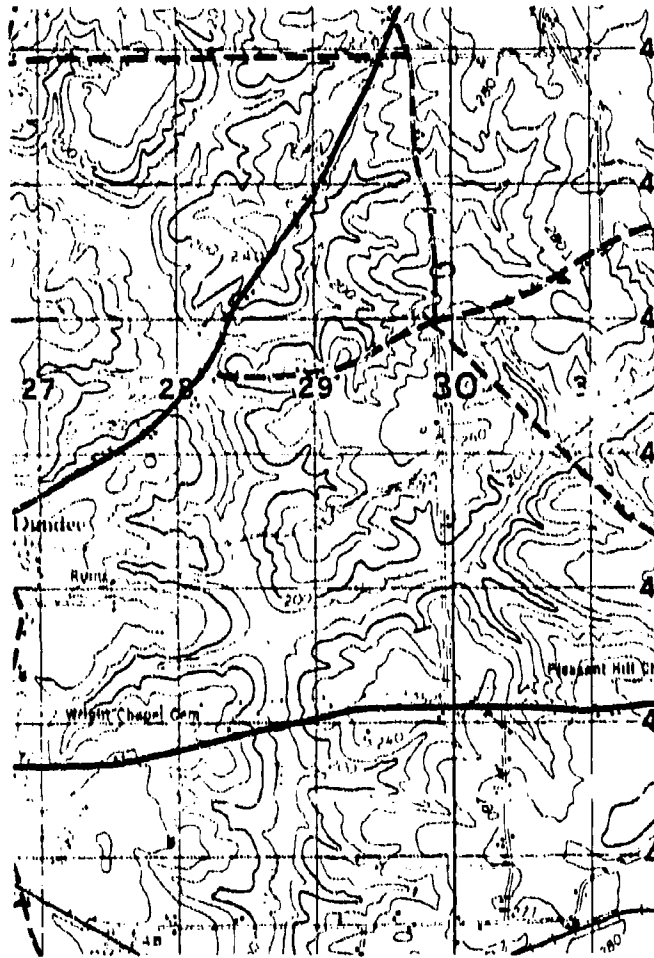
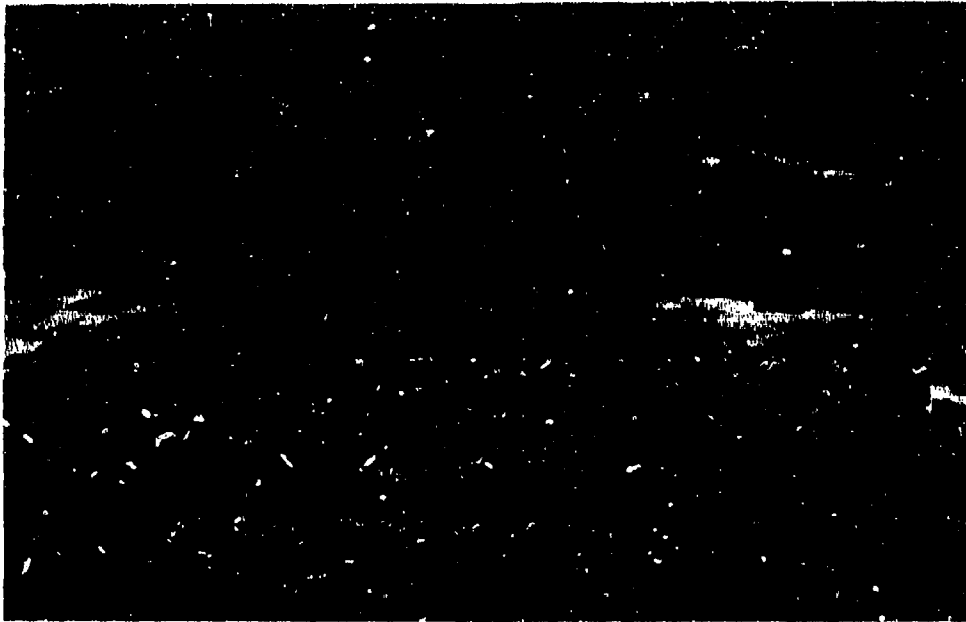


FIGURE 14. Topographic Map of Rolling Farmland.
Scale is 1:50,000; contour interval is 40 ft.



(a) Aerial view.



(b) Ground view.

FIGURE 15. Photographs of Rolling Farmland With Close Forests.

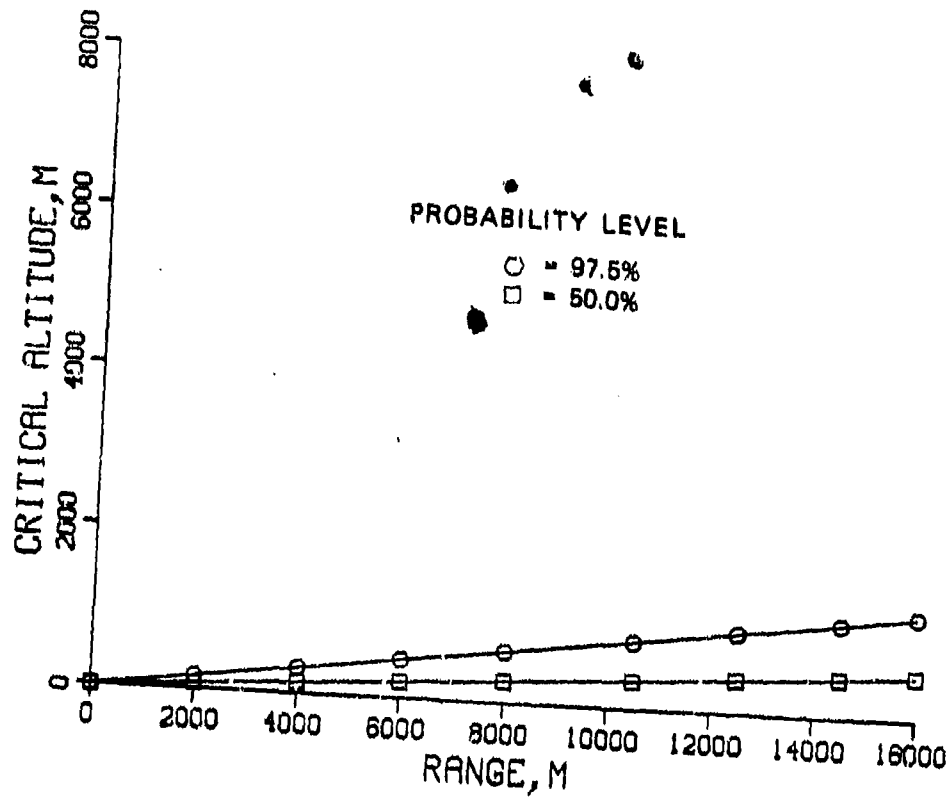
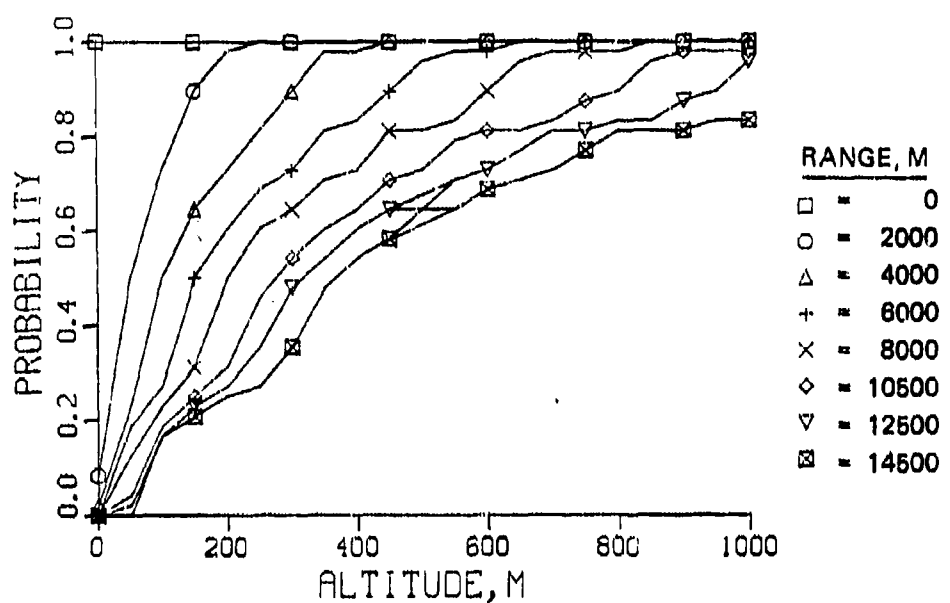
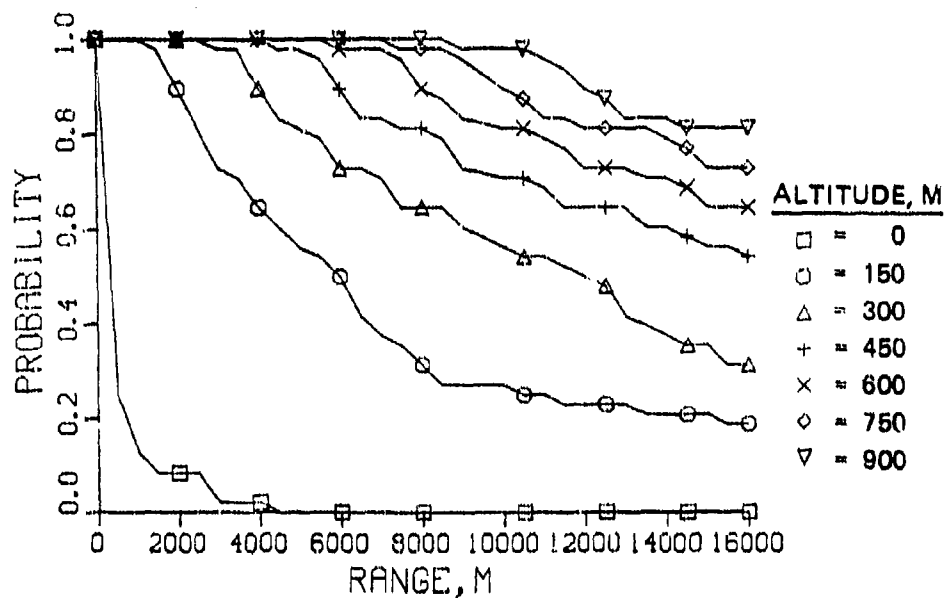


FIGURE 16. Critical Altitude as a Function of Range in Gently Rolling Farmland With Close Forests.



(a)



(b)

FIGURE 17. Average Probability of LOS in Gently Rolling Farmland With Close Forests as a Function of (a) Altitude up to 1000 m, and (b) Range.

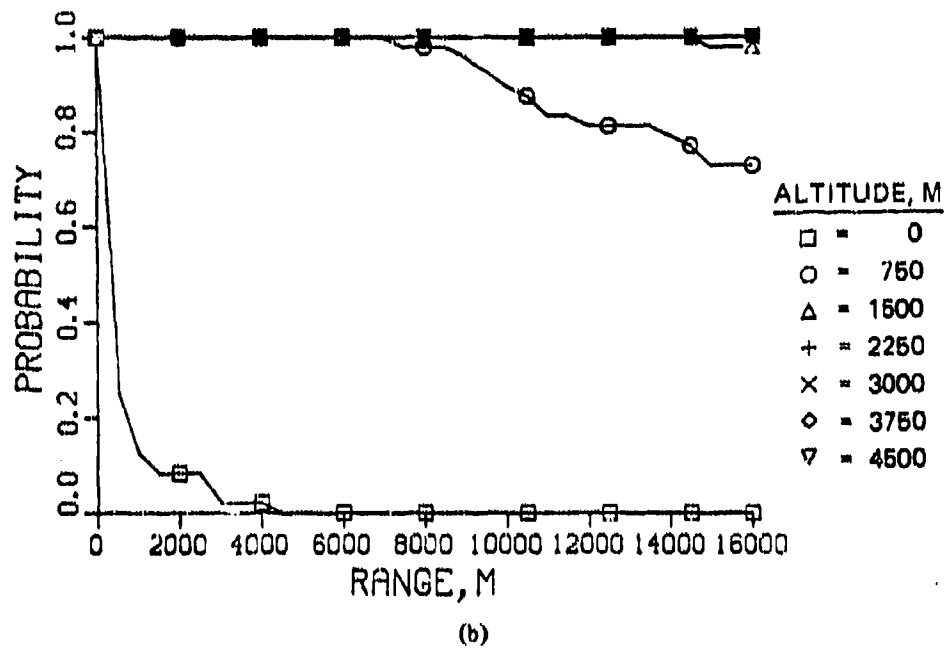
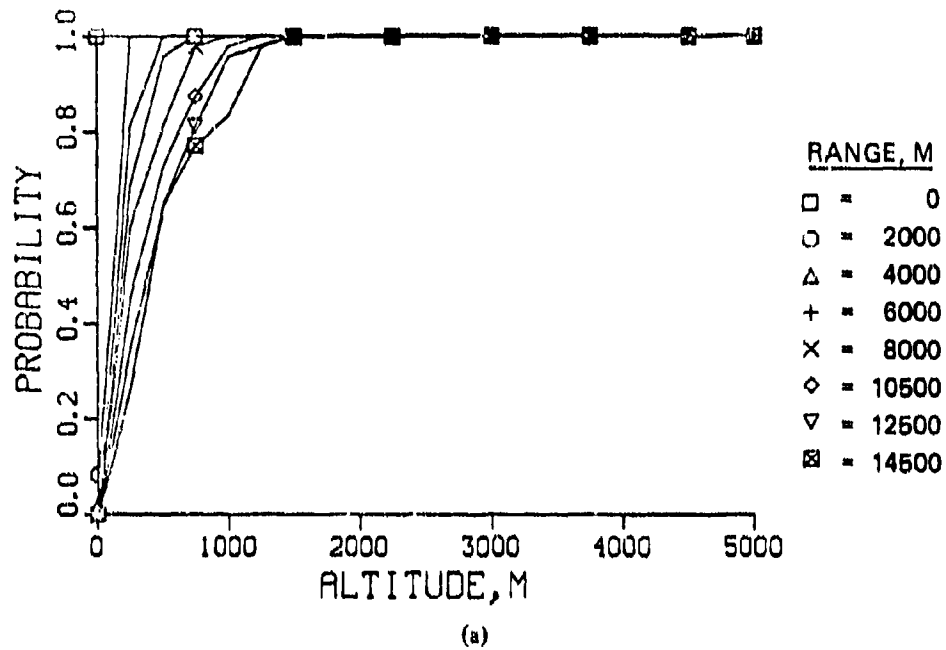
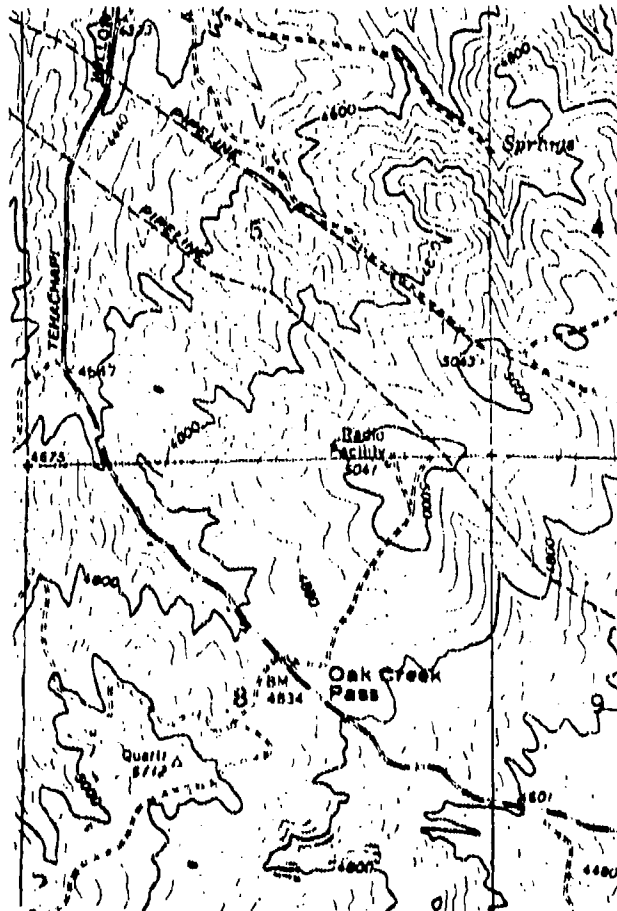


FIGURE 18. Average Probability of LOS in Gently Rolling Farmland With Close Forests as a Function of (a) Altitude up to 5000 m, and (b) Range.

**D. Moderately Rough Desert and Rolling Hills With Little
or No Vegetation (see Figures 19 through 23)**

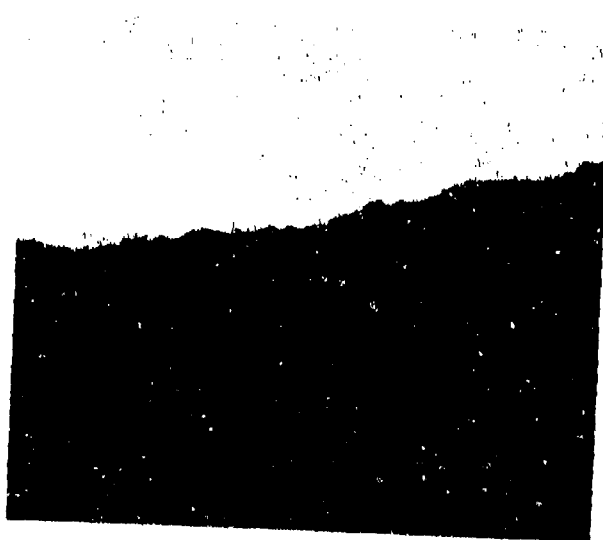
Rolling hills and moderately rough desert terrain is characterized by terrain features with high frequency and low amplitude, i.e., many small ups and downs.



**FIGURE 19. Topographic Map of Rolling Terrain.
Scale is 1:24,000; contour interval is 40 ft.**



(a) Aerial view.



(b) Ground view.

FIGURE 20. Photographs of Moderately Rough Desert Terrain.

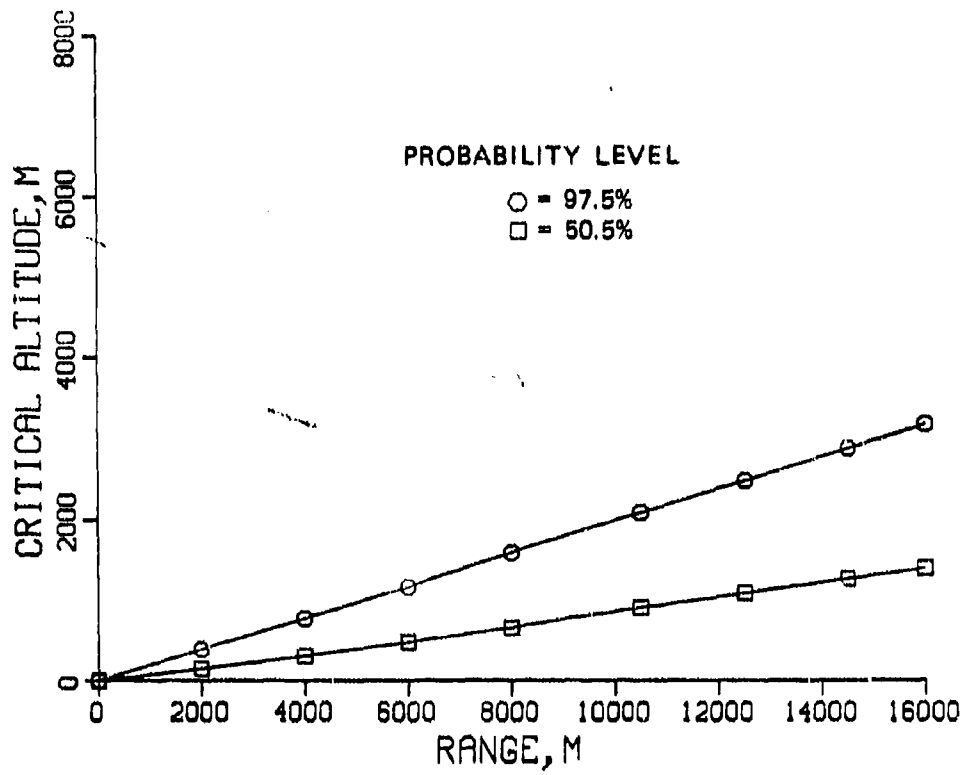
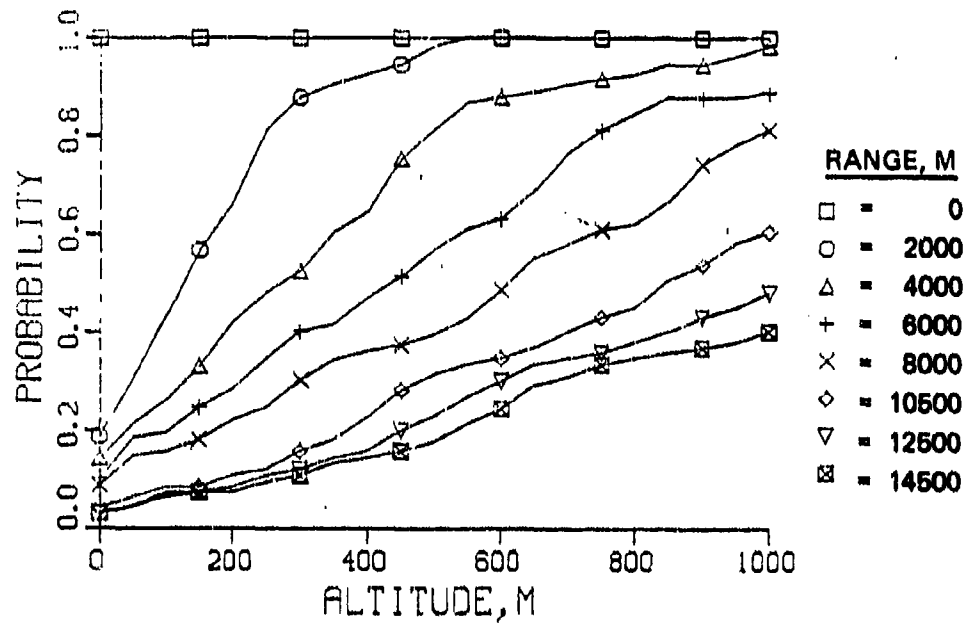
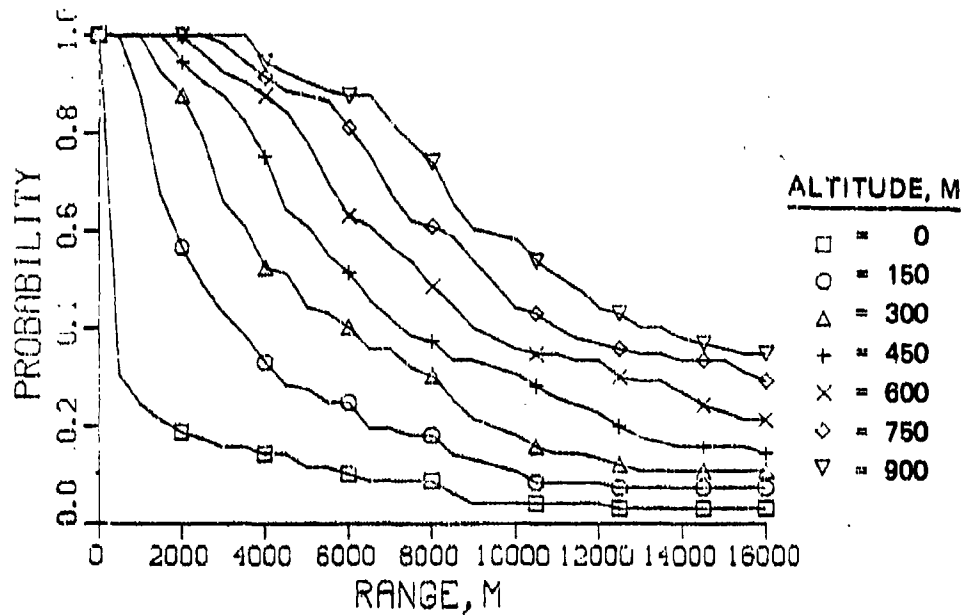


FIGURE 21. Critical Altitude as a Function of Range in Moderately Rough Desert or Rolling Hills With Little Vegetation.

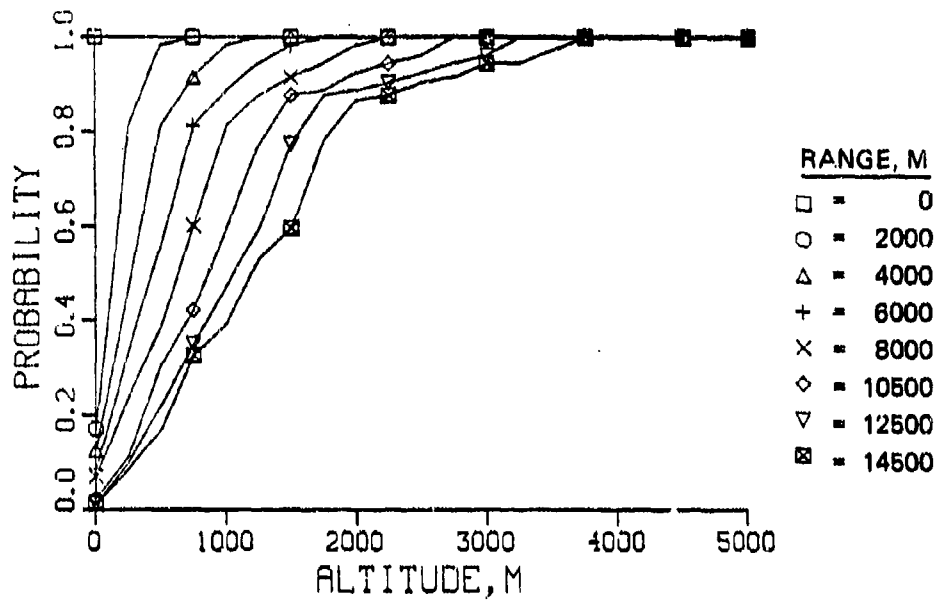


(a)

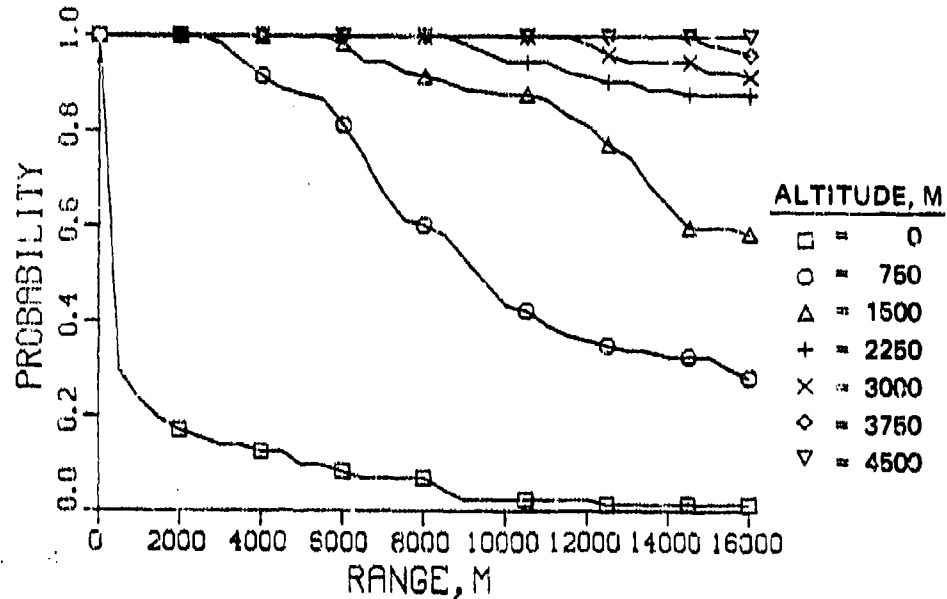


(b)

FIGURE 22. Average Probability of LOS in Moderately Rough Desert or Rolling Hills With Little Vegetation as a Function of (a) Altitude up to 1000 m, and (b) Range.



(a)



(b)

FIGURE 23. Average Probability of LOS in Moderately Rough Desert or Rolling Hills With Little or No Vegetation as a Function of (a) Altitude up to 5000 m, and (b) Range.

E. Flat Farmland With Close Forests (see Figures 24 through 28)

This terrain type consists of fairly small fields cleared in dense forests on flat land.

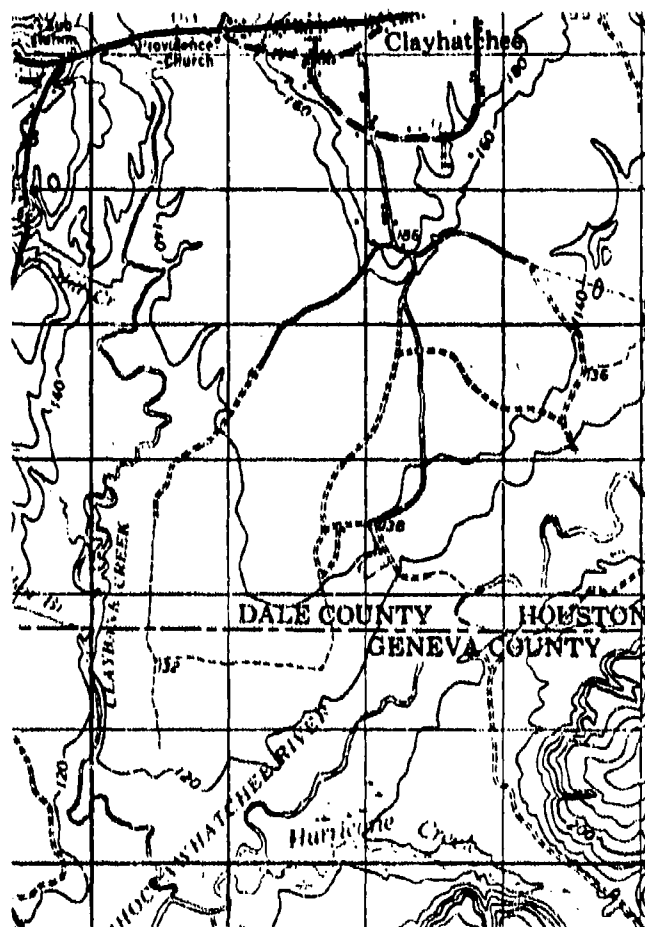
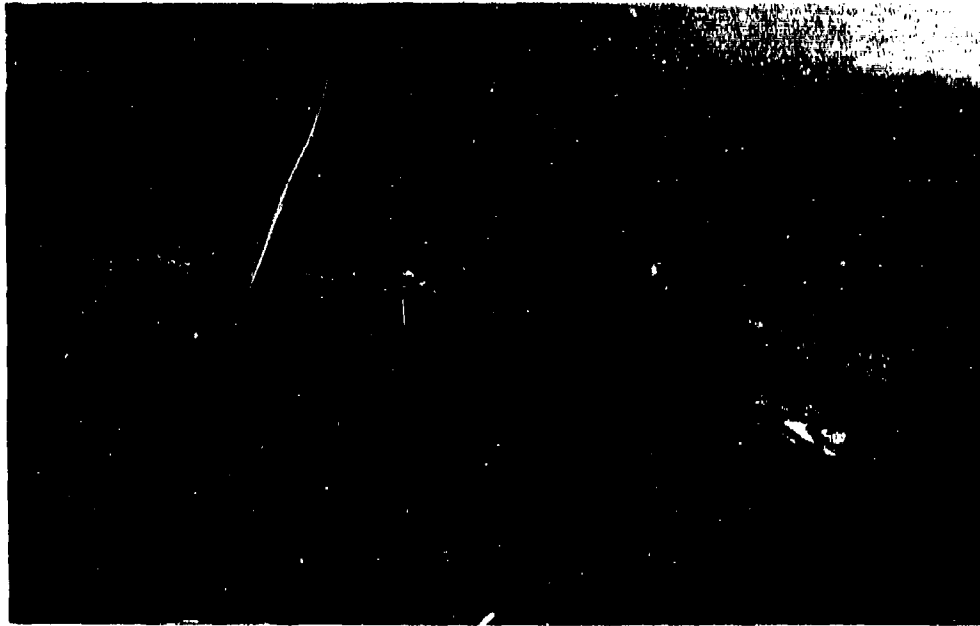


FIGURE 24. Topographic Map of Flat Farmland.
Scale is 1:50,000; contour interval is 20 ft.



(a) Aerial view.



(b) Ground view.

FIGURE 25. Photographs of Flat Farmland With Close Forests.

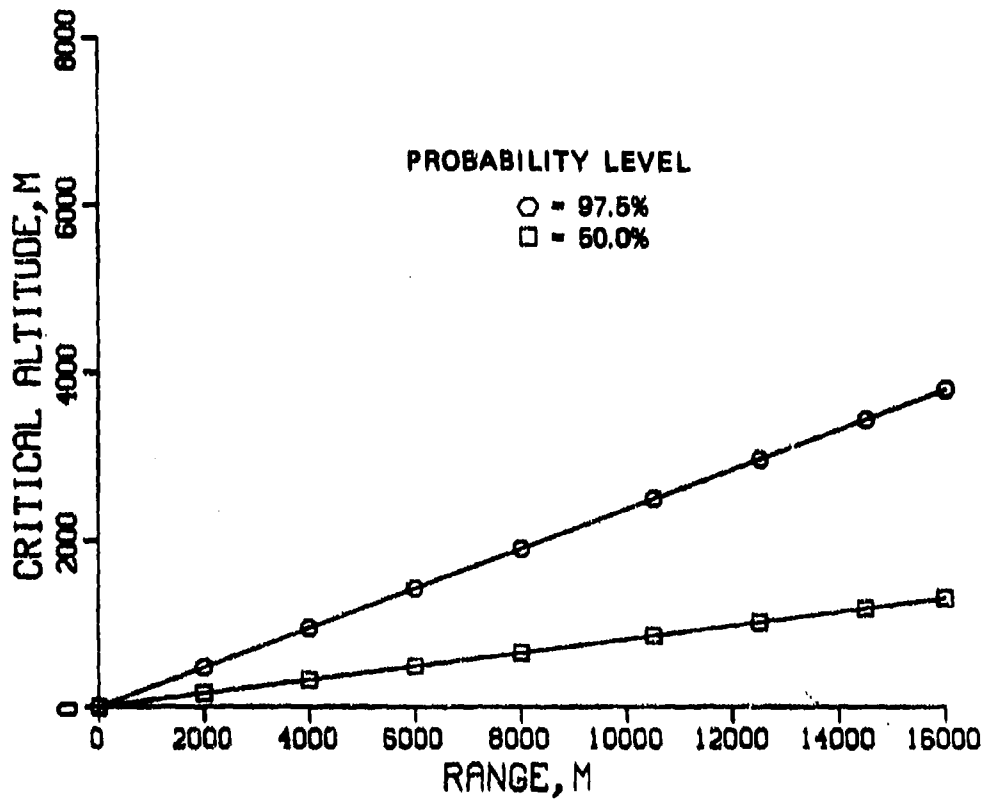


FIGURE 26. Critical Altitude as a Function of Range in Flat Farmland With Close Forests.

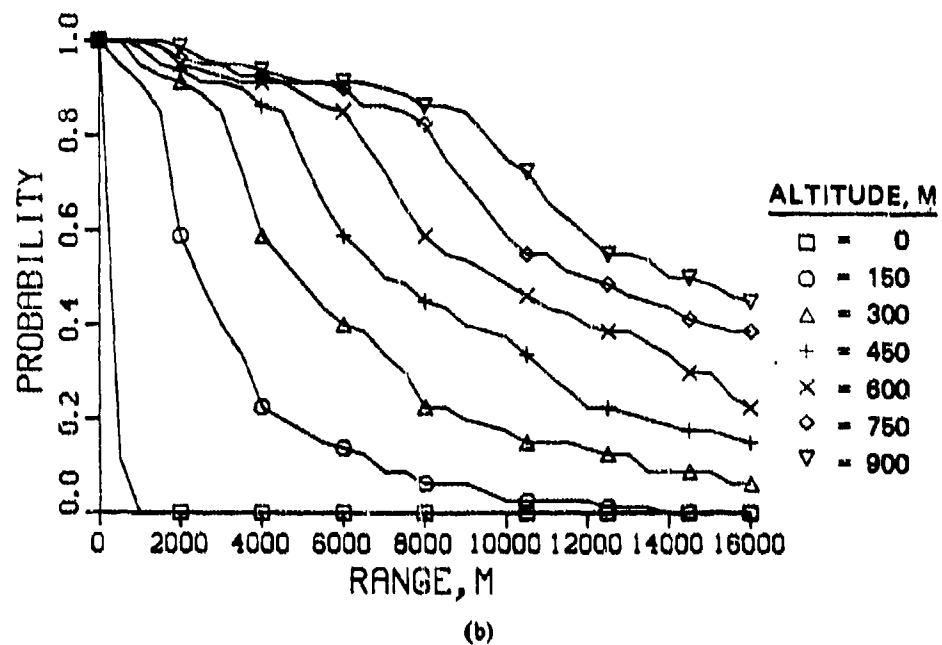
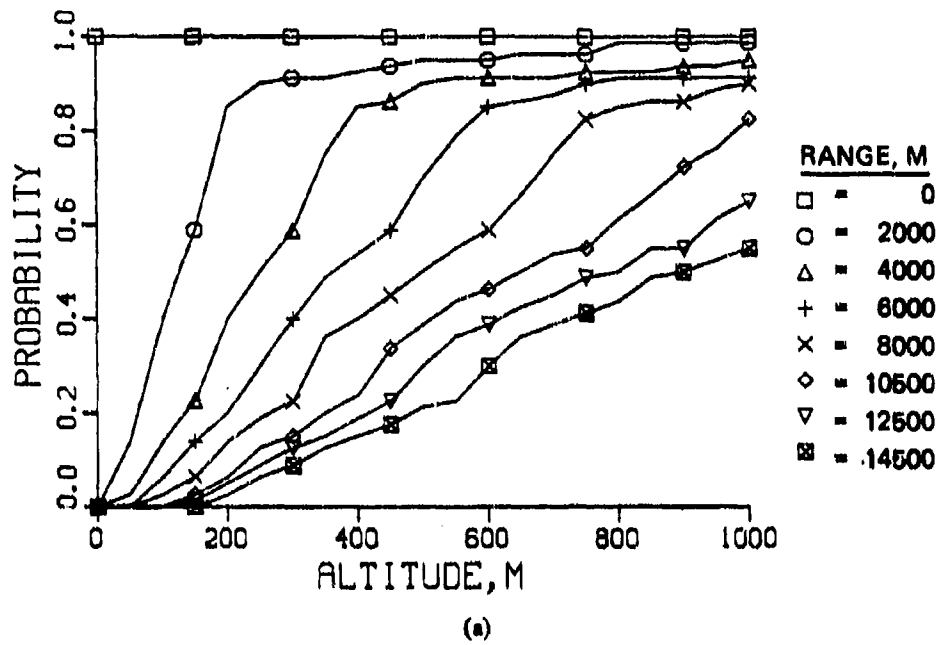


FIGURE 27. Average Probability of LOS in Flat Farmland With Clove Forests as a Function of (a) Altitude up to 1000 m, and (b) Range.

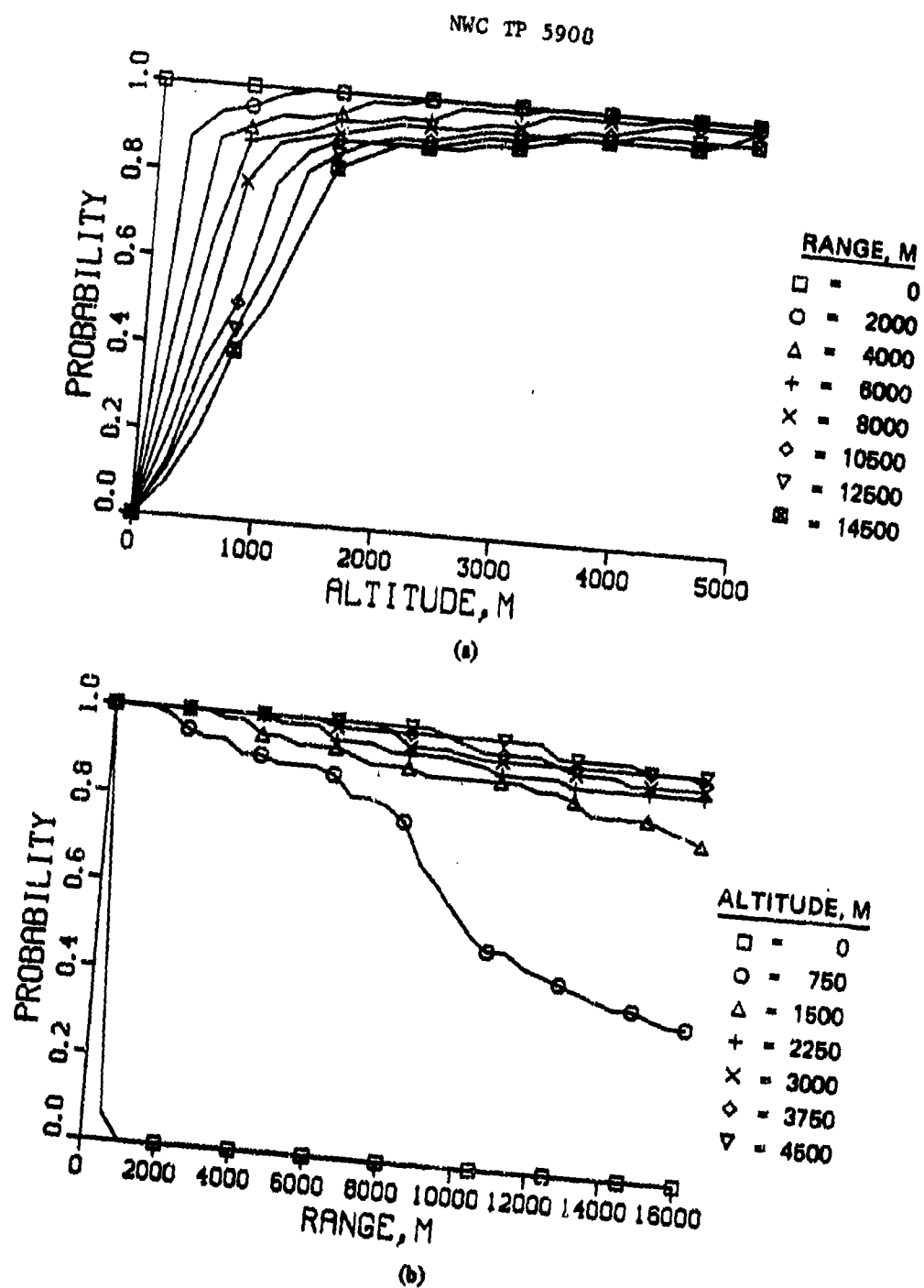


FIGURE 28. Average Probability of LOS in Flat Farmland With Close Forests as a Function of (a) Altitude up to 5000 m, and (b) Range.

F. Gently Rolling Hills With Scattered Trees (see Figures 29 through 33)

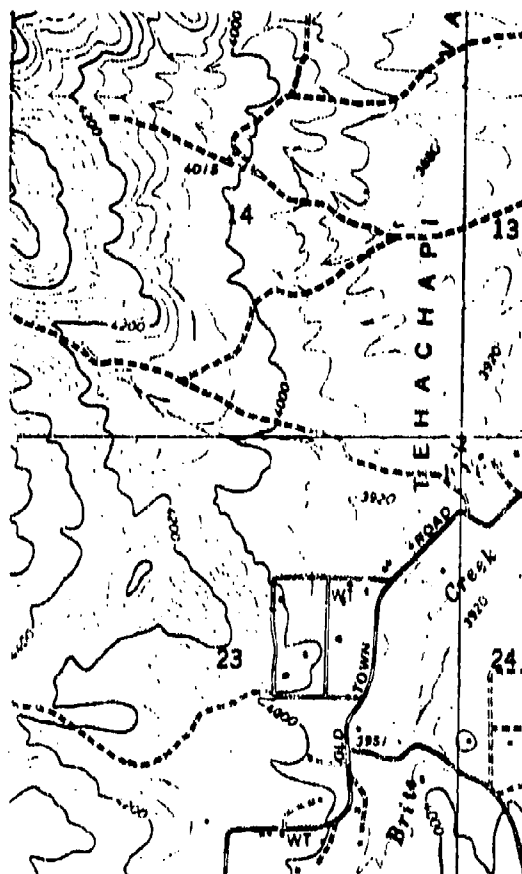


FIGURE 29. Topographic Map of Gently Rolling Hills. Scale is 1:24,000; contour interval is 40 ft.



(a) Aerial view.



(b) Ground view.

FIGURE 30. Photographs of Gently Rolling Hills With Scattered Trees.

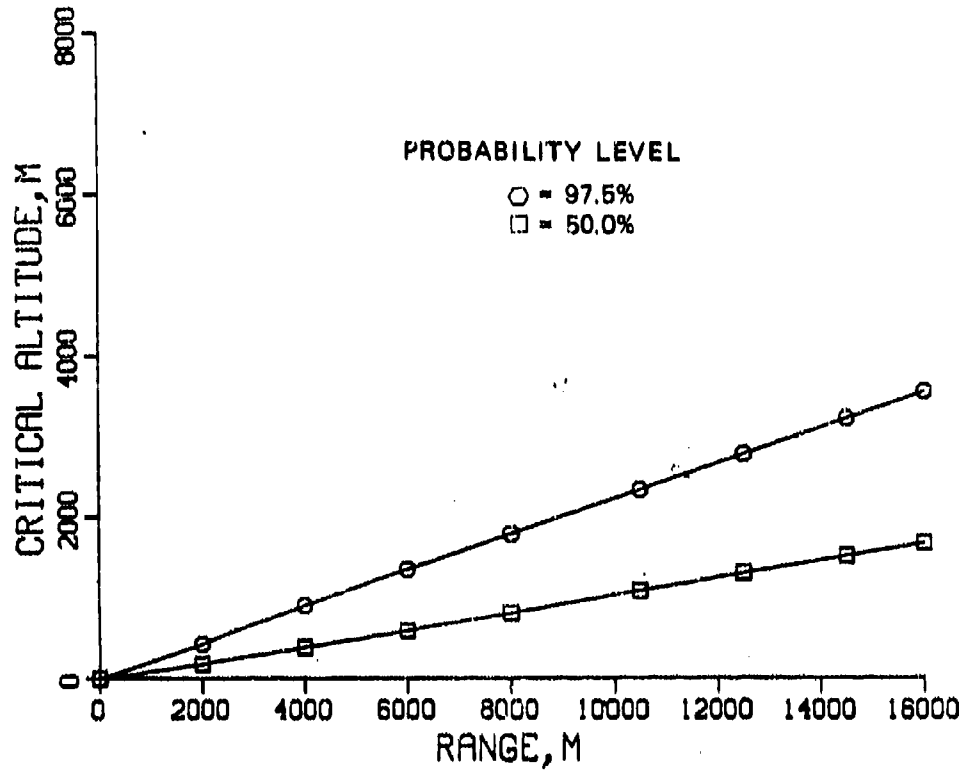
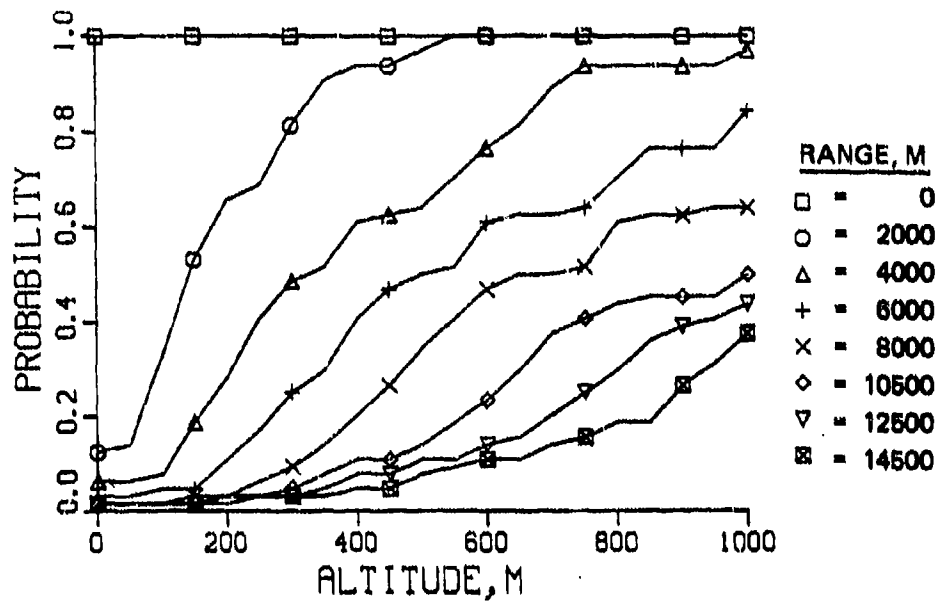
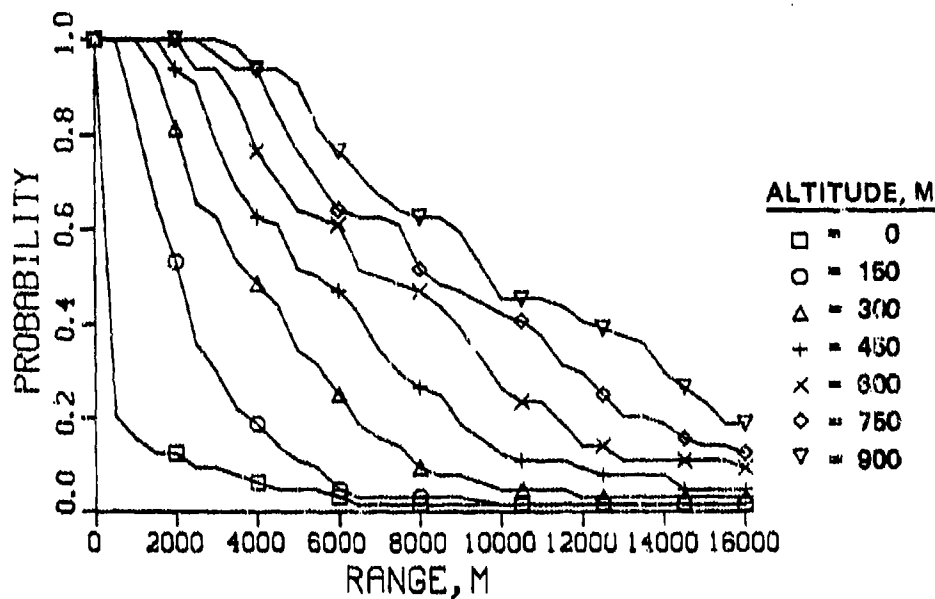


FIGURE 31. Critical Altitude as a Function of Range in Gently Rolling Hills With Scattered Trees.

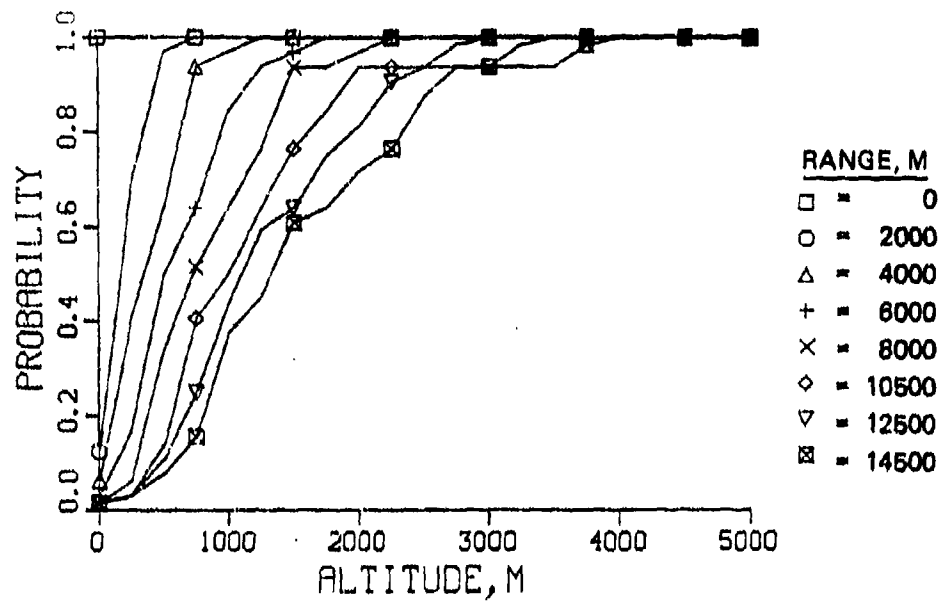


(a)

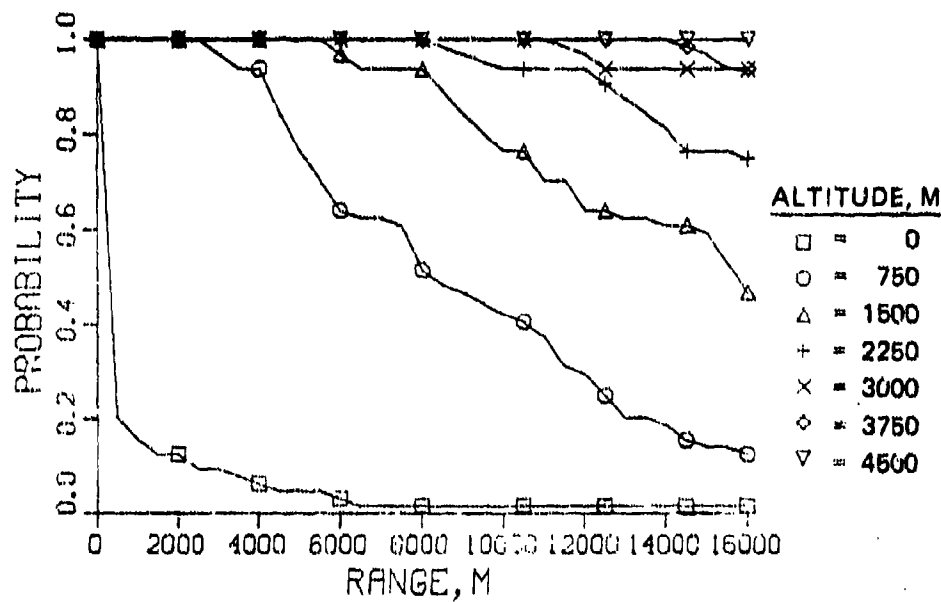


(b)

FIGURE 32. Average Probability of LOS in Gently Rolling Hills With Scattered Trees as a Function of (a) Altitude up to 1000 m, and (b) Range.



(a)



(b)

FIGURE 33. Average Probability of LOS in Gently Rolling Hills With Scattered Trees as a Function of (a) Altitude up to 5000 m, and (b) Range.

G. Rough Desert With Little or No Vegetation (see Figures 34 through 38)

This terrain is characterized by steep, rocky gullies and ridges.

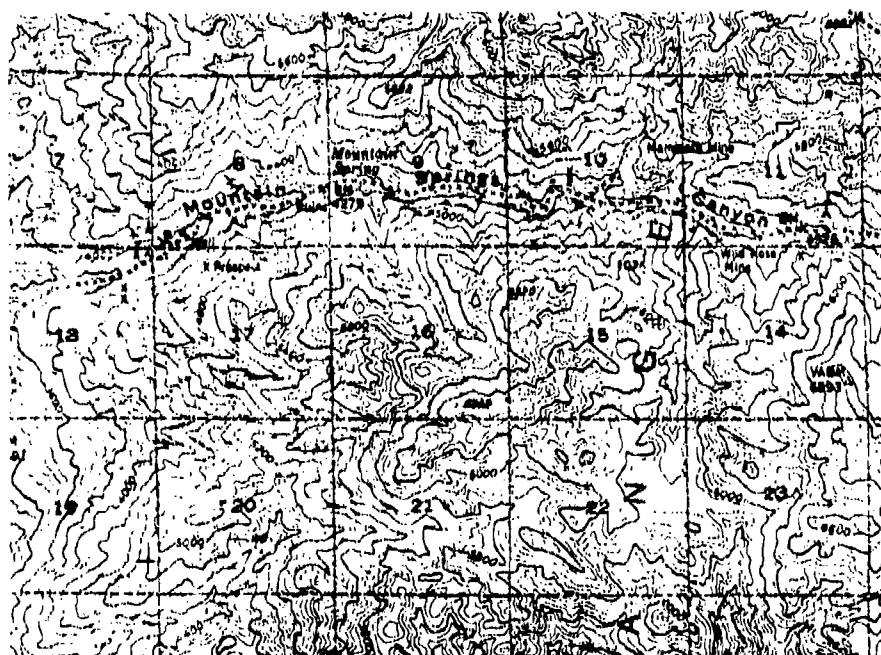
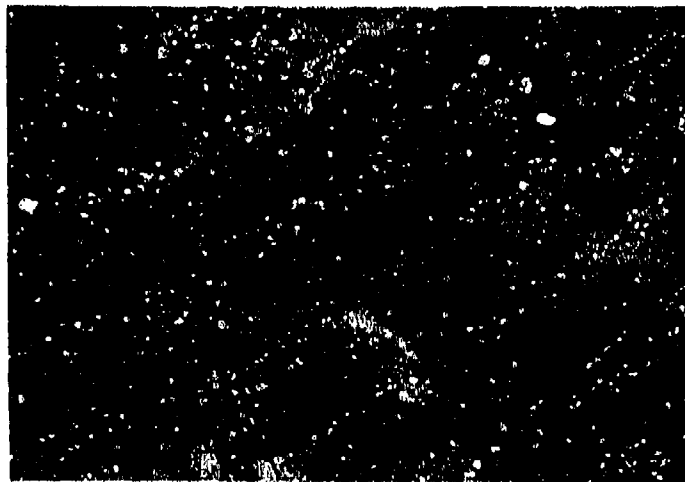


FIGURE 34. Topographic Map of Rough Desert.
Scale is 1:62,500; contour interval is 40 ft.



(a) Aerial view.



(b) Ground view.

FIGURE 35. Photographs of Rough Desert With Little or No Vegetation.

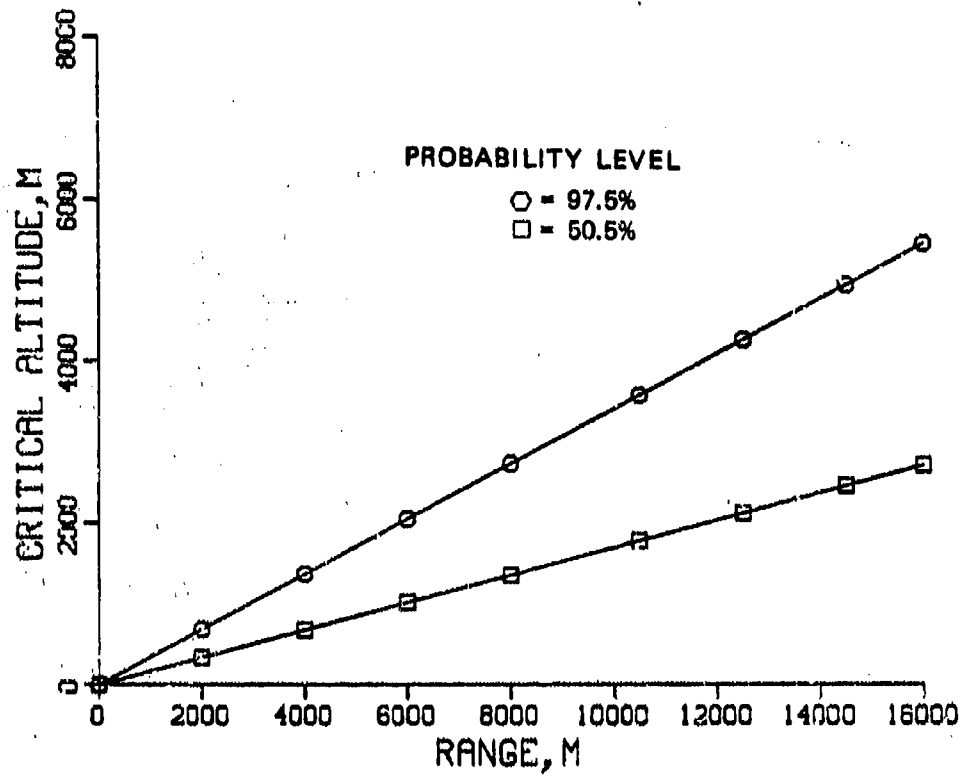


FIGURE 36. Critical Altitude as a Function of Range in Rough Desert With Little Vegetation.

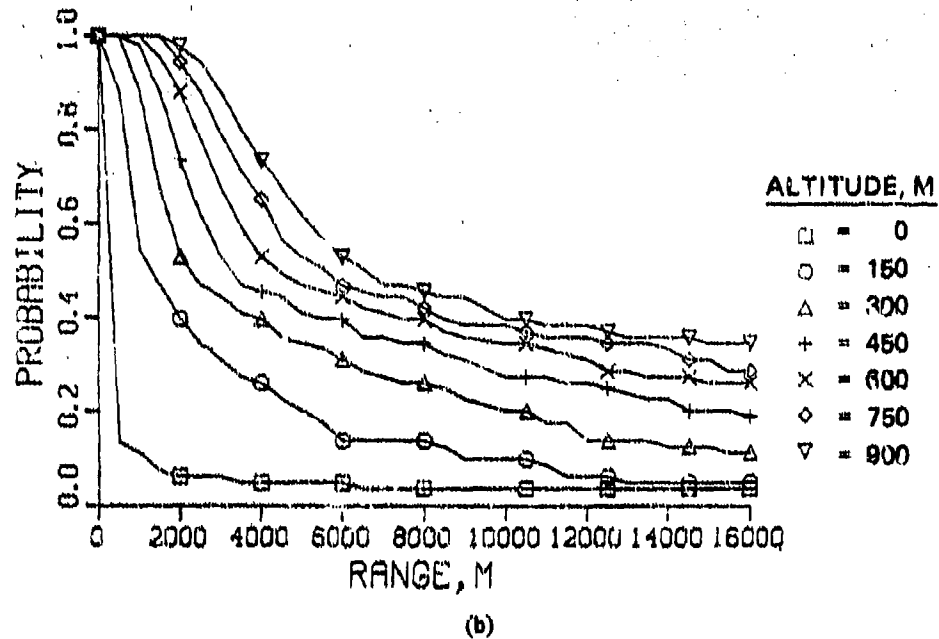
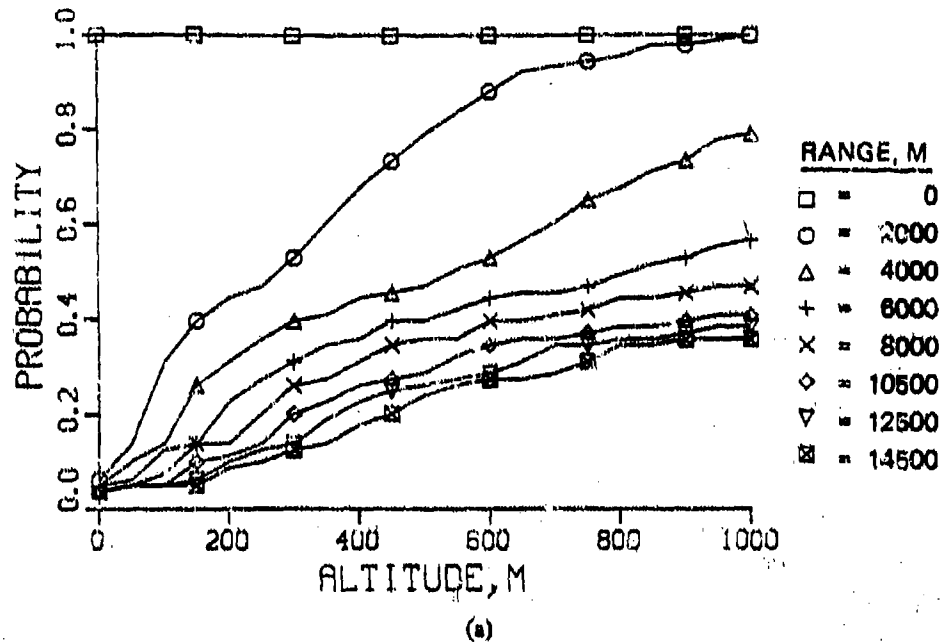
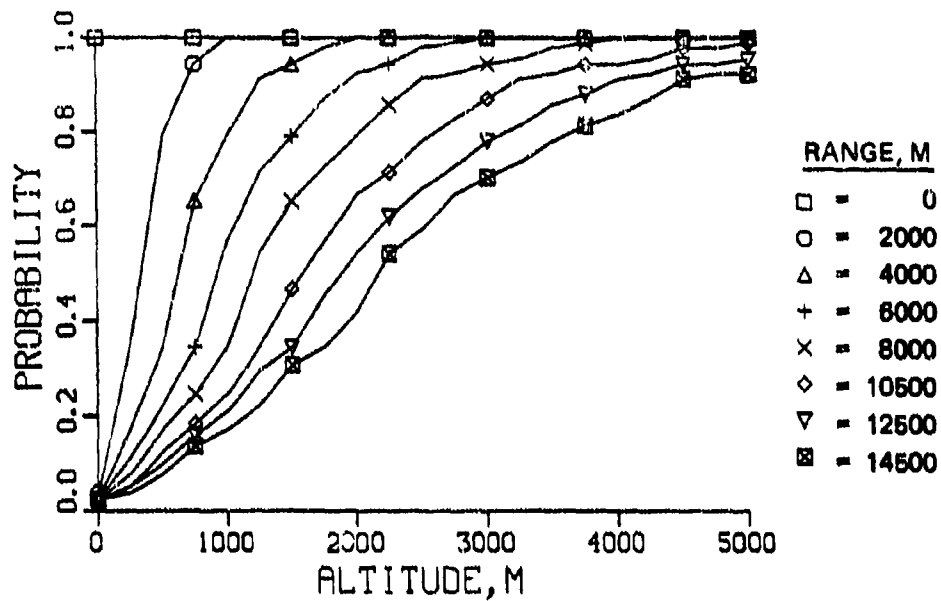
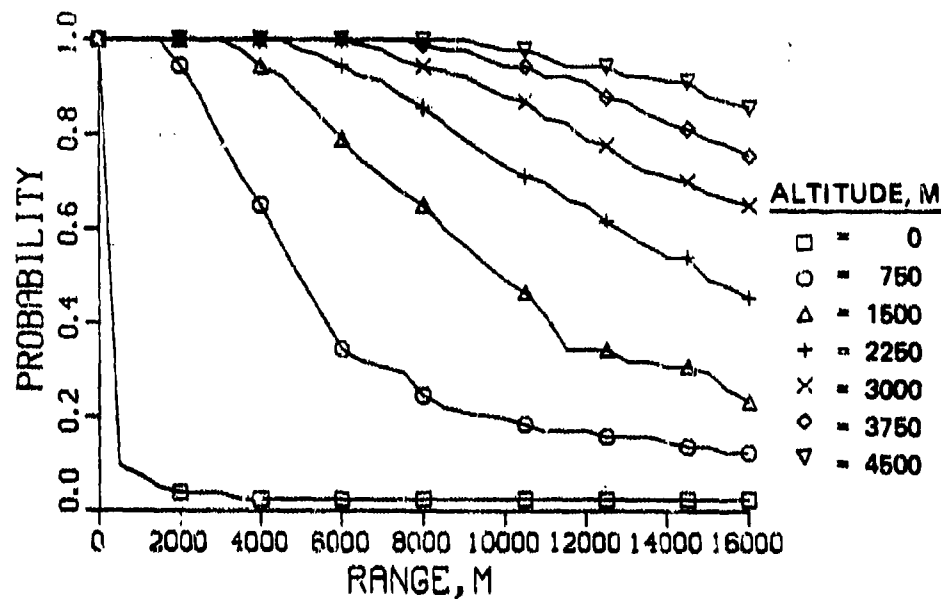


FIGURE 37. Average Probability of LOS in Rough Desert With Little Vegetation as a Function of (a) Altitude up to 1000 m and (b) Range.



(a)



(b)

FIGURE 38. Average Probability of LOS in Rough Desert With Little Vegetation as a Function of (a) Altitude up to 5000 m and (b) Range.

H. Sharply Rolling Hills With Thickly Scattered Trees (see Figures 39 through 43)

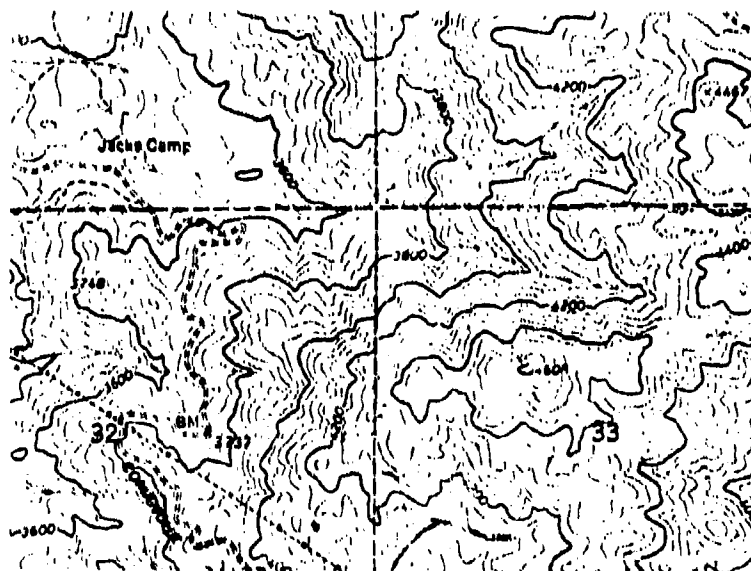
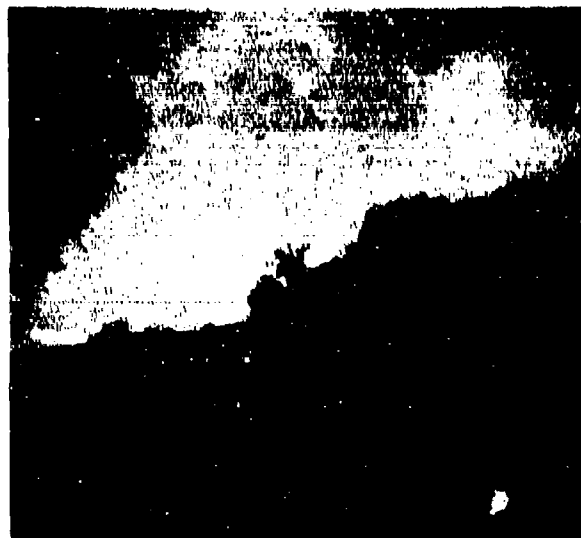


FIGURE 39. Topographic Map of Sharply Rolling Hills. Scale is 1:24,000; contour interval is 40 ft.



(a) Aerial view.



(b) Ground view.

FIGURE 40. Photographs of Sharply Rolling Terrain With Thickly Scattered Trees.

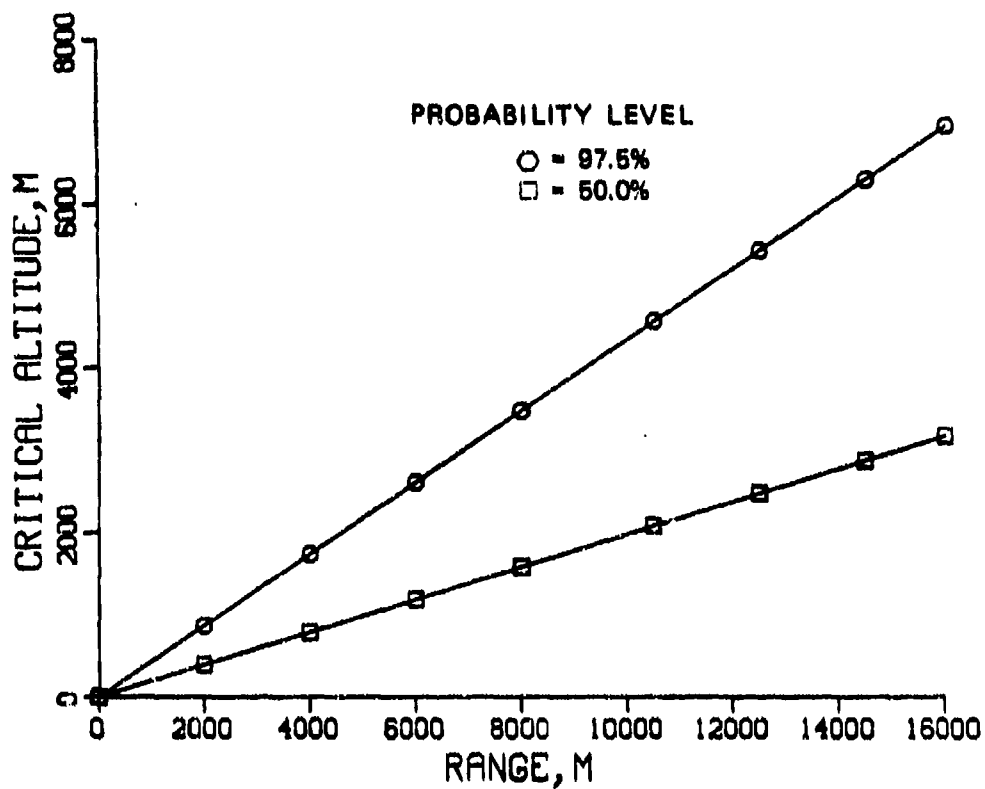


FIGURE 41. Critical Altitude as a Function of Range in Sharply Rolling Hills With Thickly Scattered Trees.

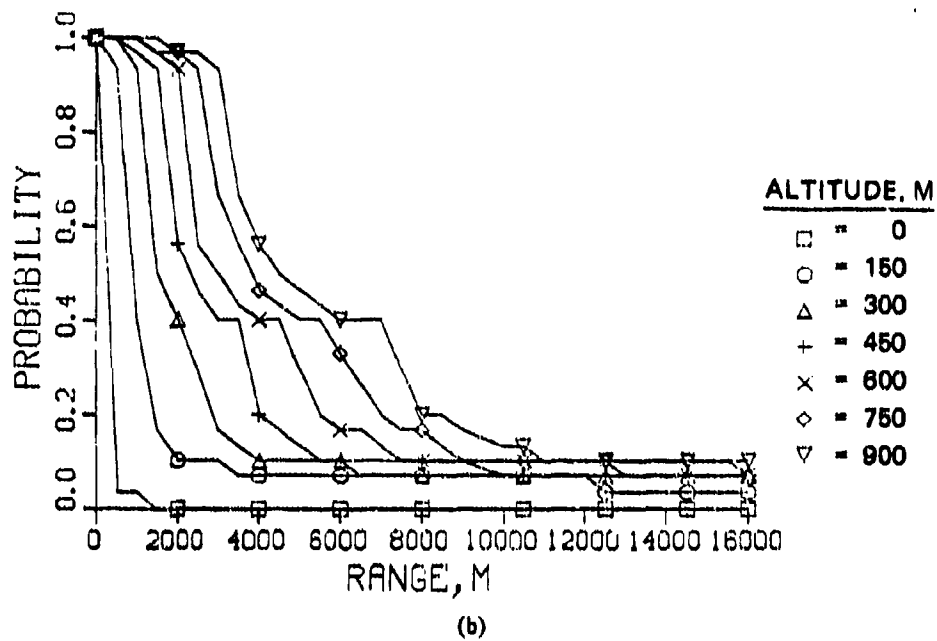
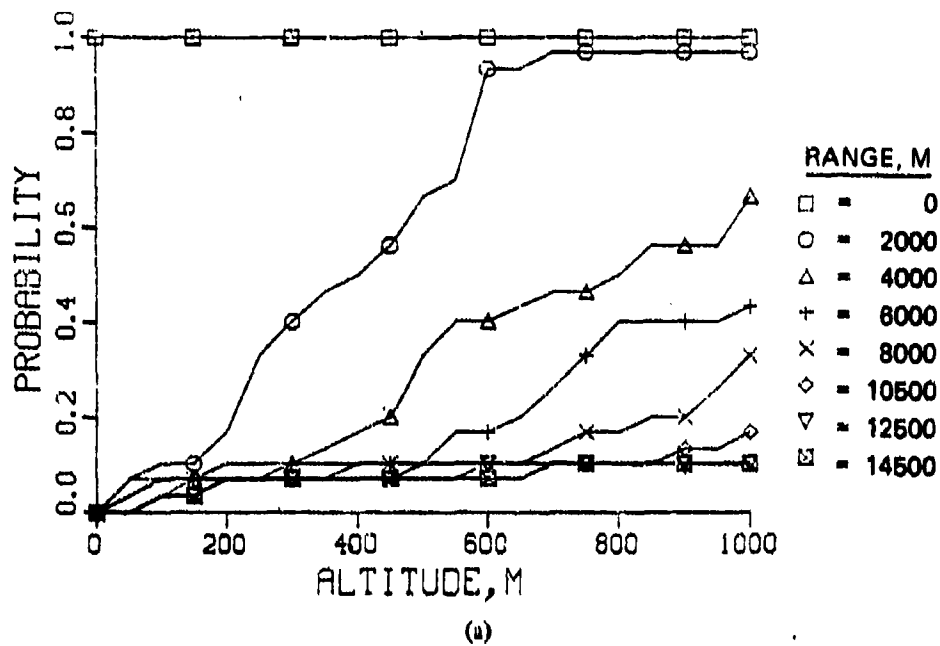
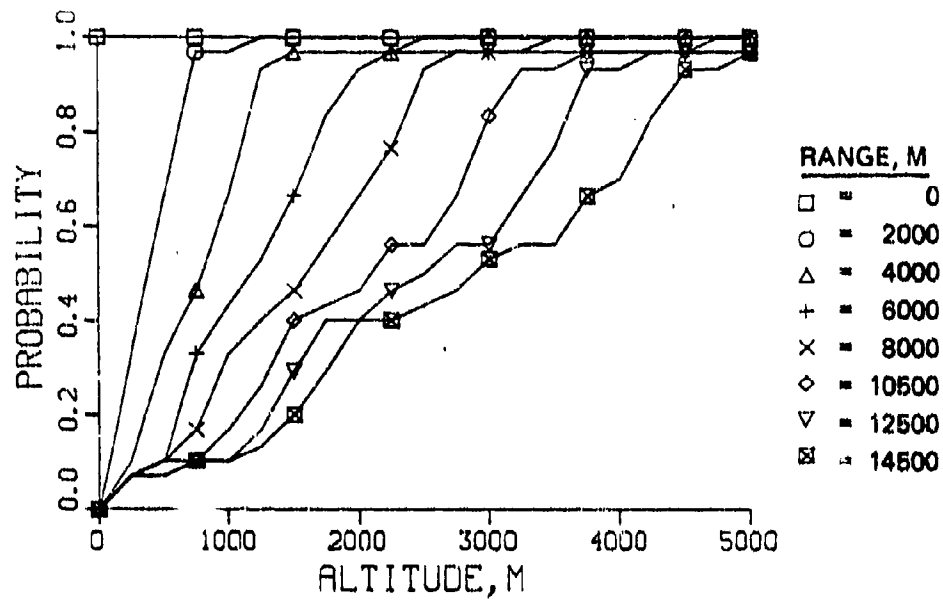
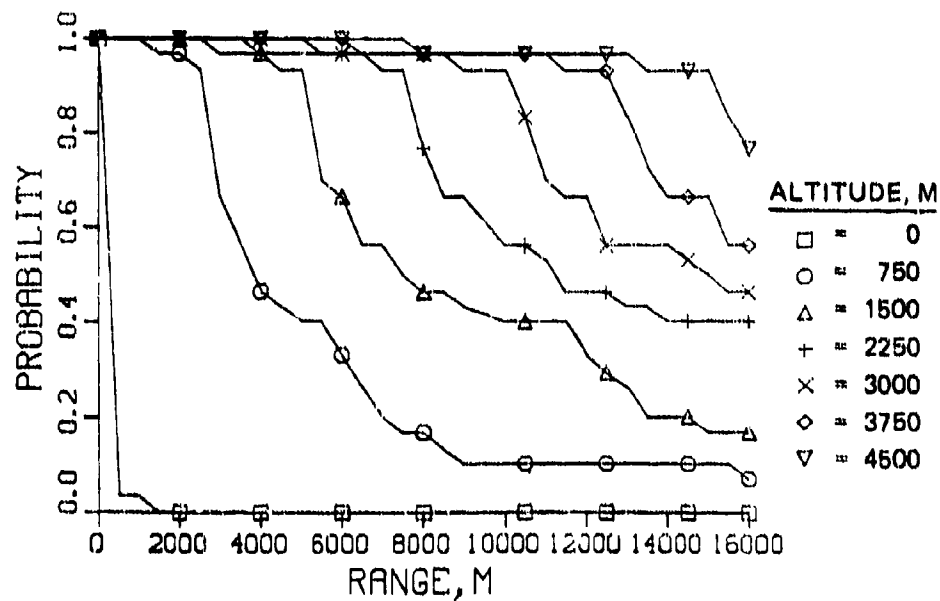


FIGURE 42. Average Probability of LOS in Sharply Rolling Hills With Thickly Scattered Trees as a Function of (a) Altitude up to 1000 m, and (b) Range.



(a)



(b)

FIGURE 43. Average Probability of LOS in Sharply Rolling Hills With Thickly Scattered Trees as a Function of (a) Altitude up to 5000 m, and (b) Range.

DATA COLLECTED FROM UNITED KINGDOM

The next group of data was taken from sites in the United Kingdom. Critical altitudes were plotted only for the 50% level, and probability of LOS for altitudes only up to 1000 m. No photographs or maps of the terrain are available.

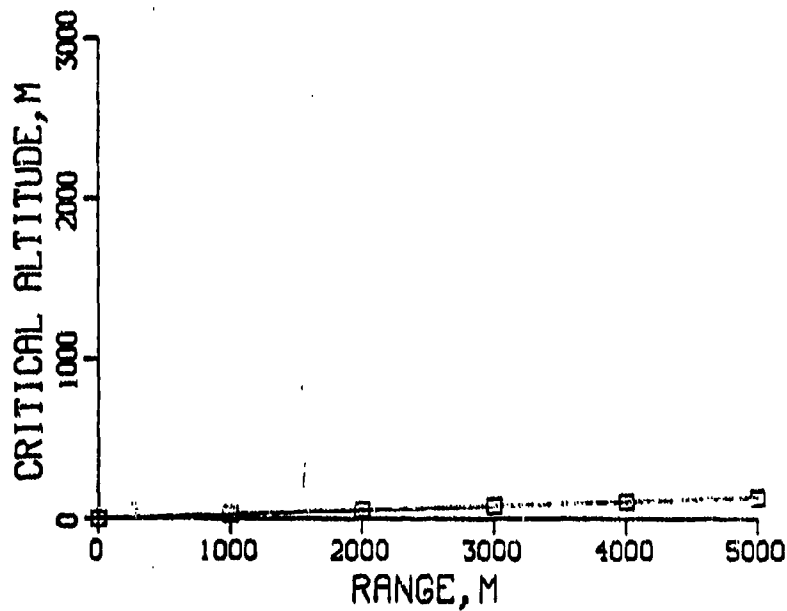
I. Most Open Terrain (see Figures 44 and 45)

FIGURE 44. Critical Altitude as a Function of Range in Most Open British Countryside.

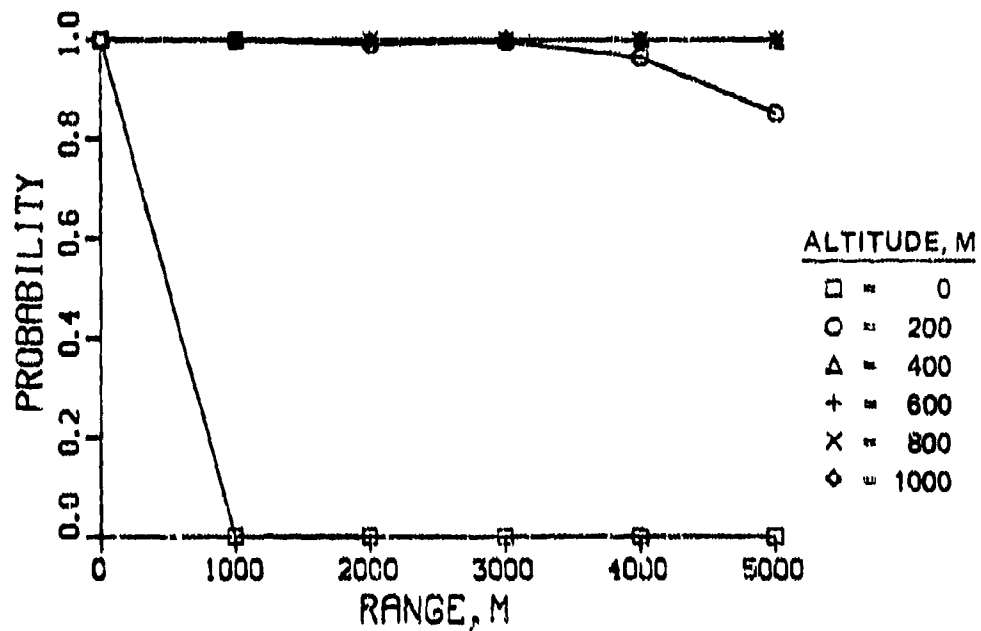
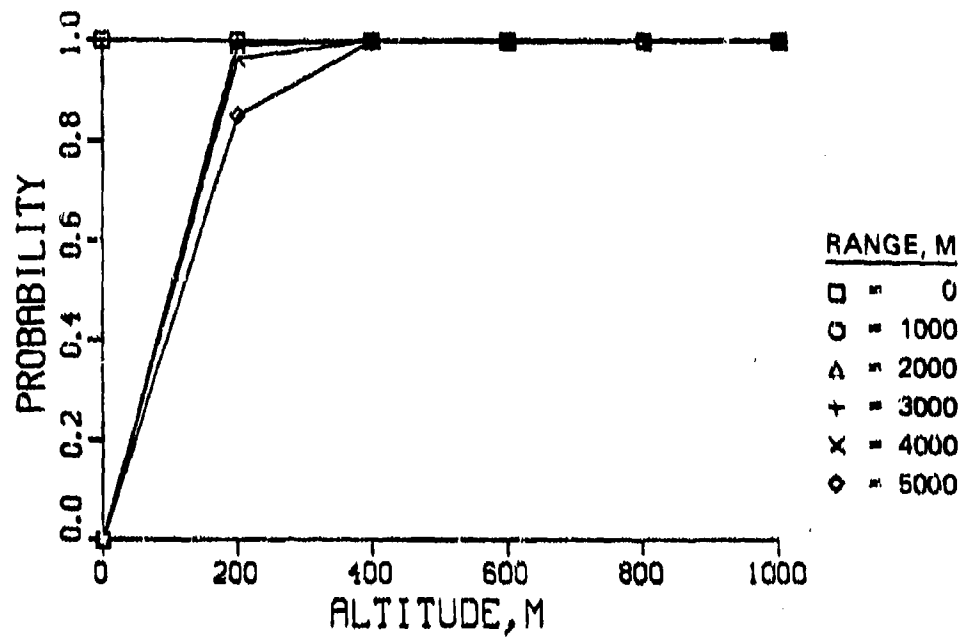


FIGURE 45. Average Probability of LOS in Most Open British Countryside as a Function of (a) Altitude, and (b) Range.

J. Second Most Open Terrain (see Figures 46 and 47)

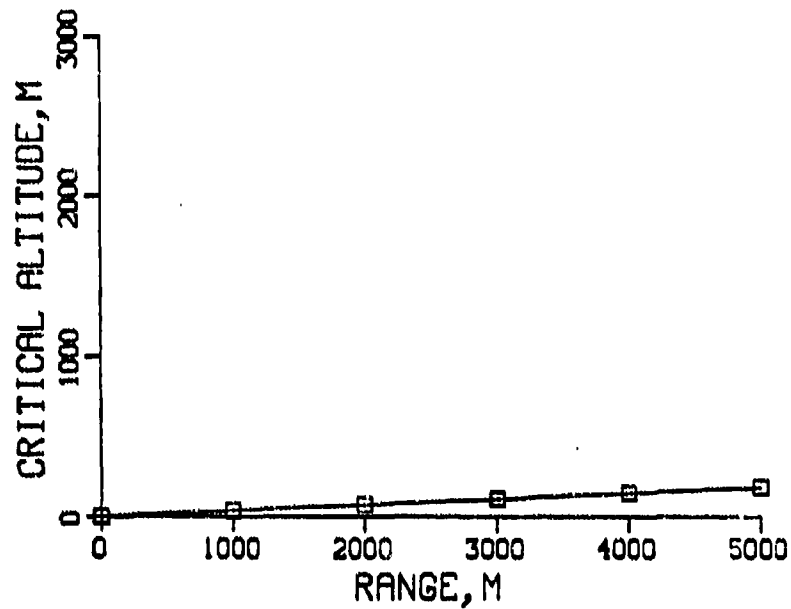
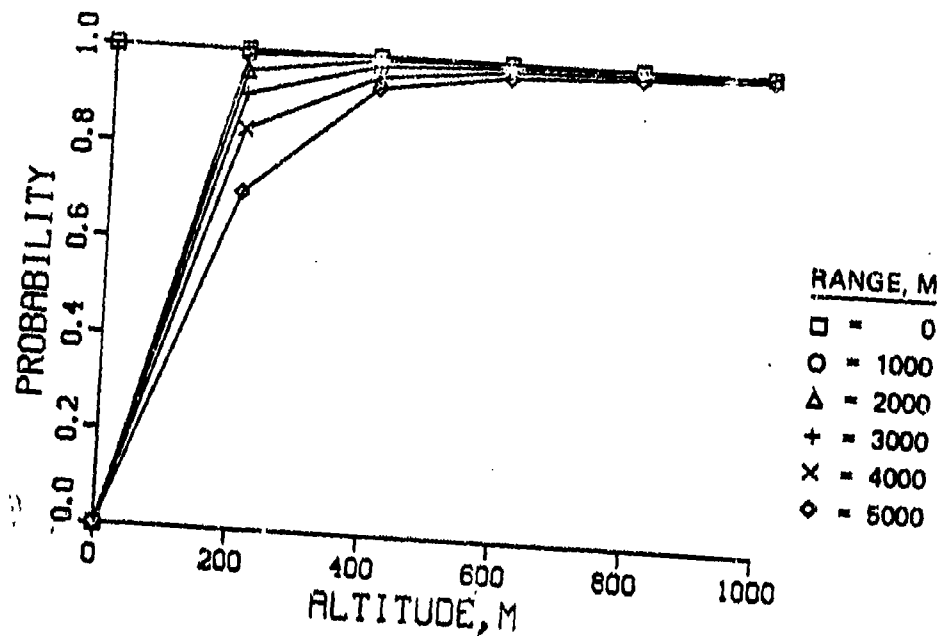
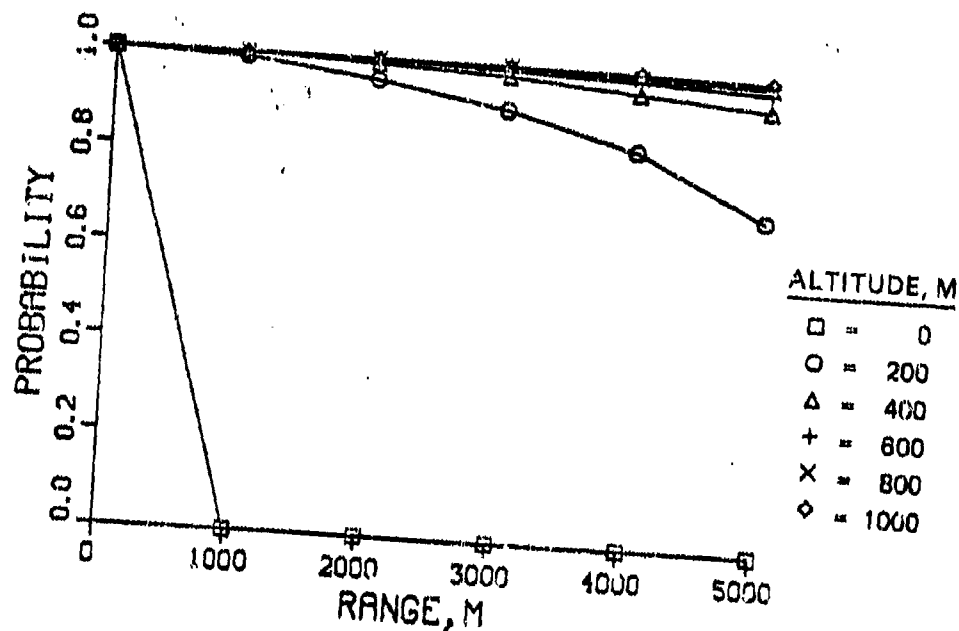


FIGURE 46. Critical Altitude as a Function of Range in Second Most Open British Countryside.



(a)



(b)

FIGURE 47. Average Probability of LOS in Second Most Open British Countryside as a Function of (a) Altitude, and (b) Range.

K. Most Closed Terrain (see Figures 48 and 49)

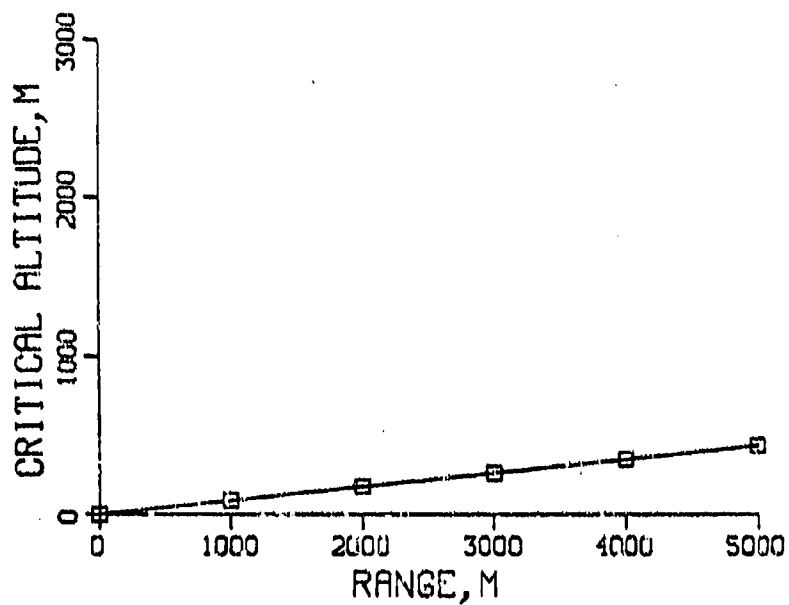


FIGURE 48. Critical Altitude as a Function of Range in Most Closed British Countryside.

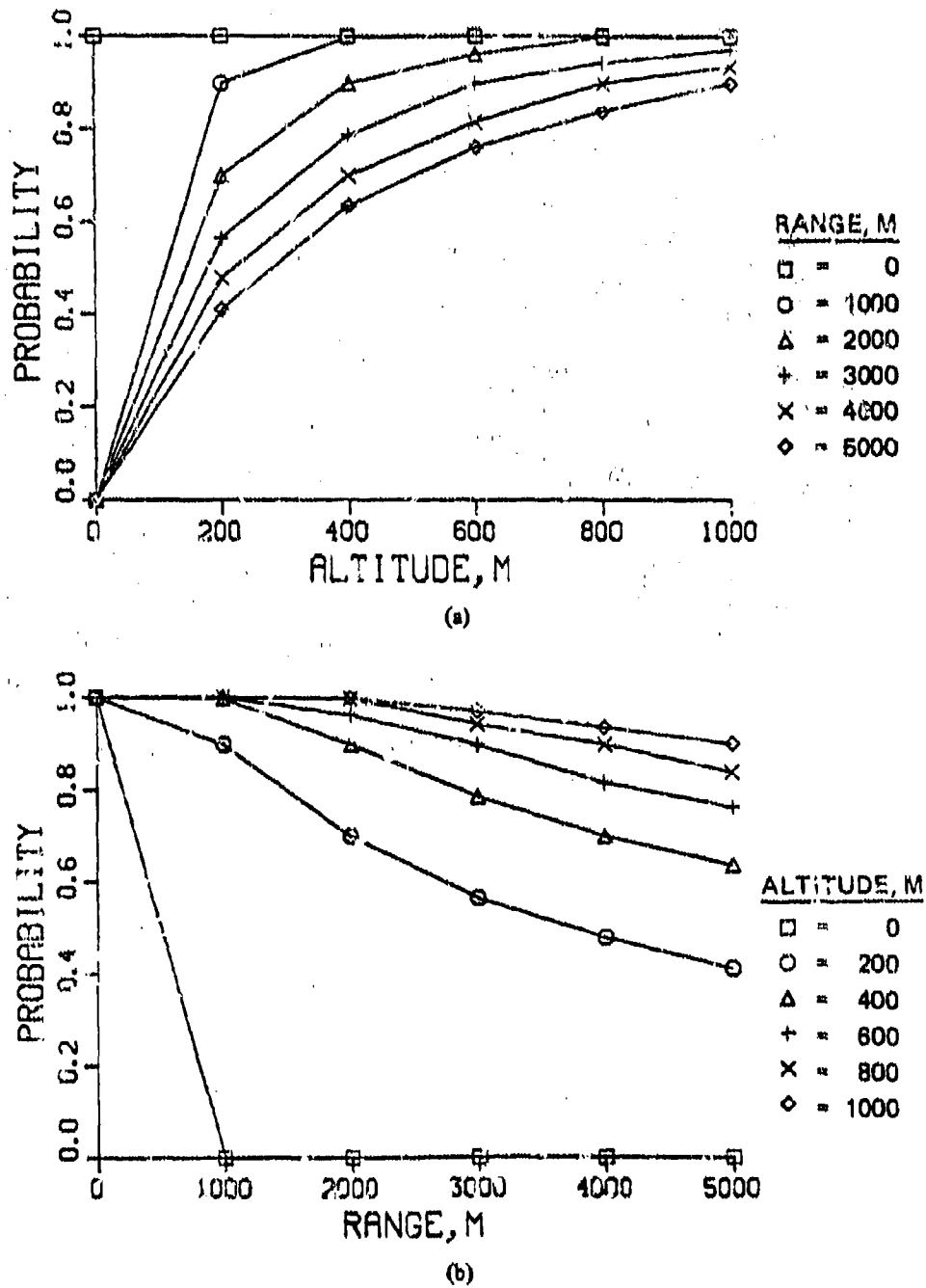


FIGURE 49. Average Probability of LOS in Most Closed British Countryside as a Function of (a) Altitude, and (b) Range.

L. Second Most Closed Terrain (see Figures 50 and 51)

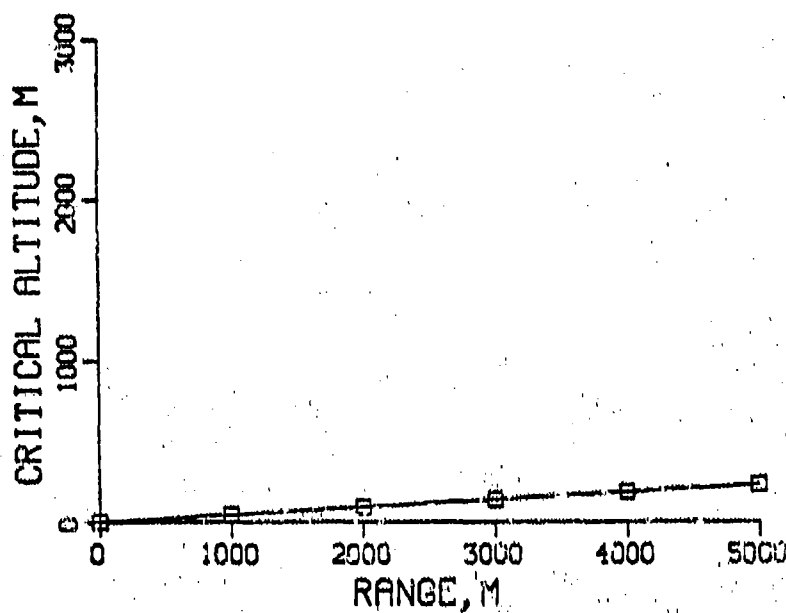


FIGURE 50. Critical Altitude as a Function of Range in Second Most Closed British Countryside.

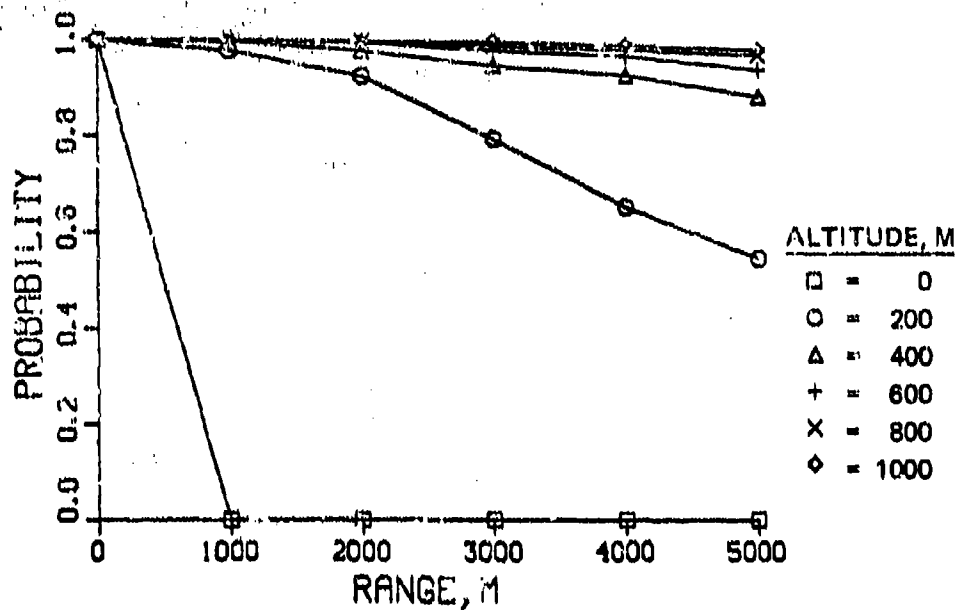
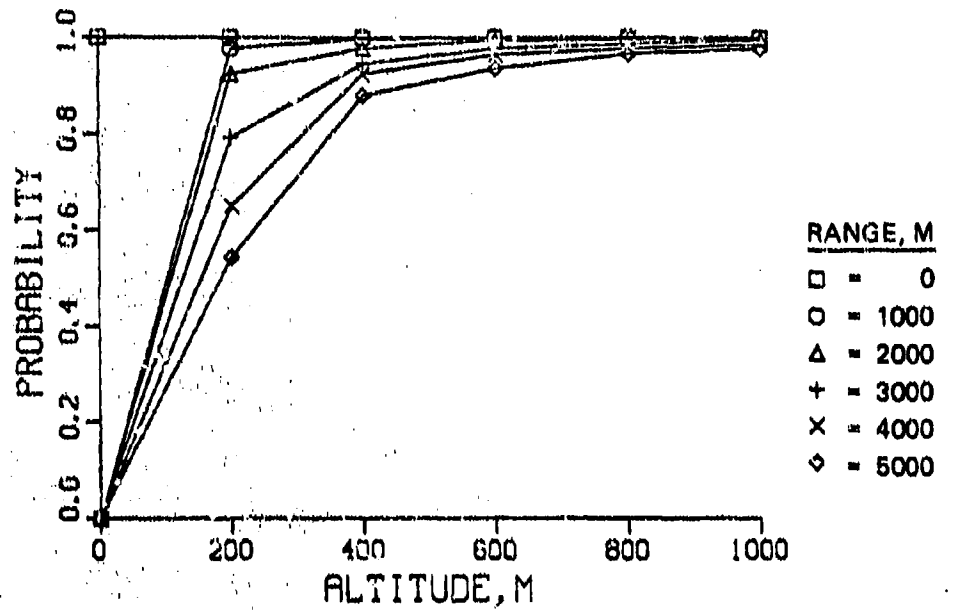


FIGURE 51. Average Probability of LOS in Second Most Closed British Countryside as a Function of (a) Altitude, and (b) Range.

NWC TP 5908

Appendix A
DATA ON INDIVIDUAL U.S. SITES SURVEYED

TERRAIN/VEGETATION TYPE A

Description: Farmland, fairly flat, with thick forest in distance.

Data available: Ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs (see Figures 52 through 71).

Number of sites surveyed: Five.

Site designations: TTH 1, TTH 2, HB 1, HF 1, ALN.

Approximate number of LOS measurements: 100.

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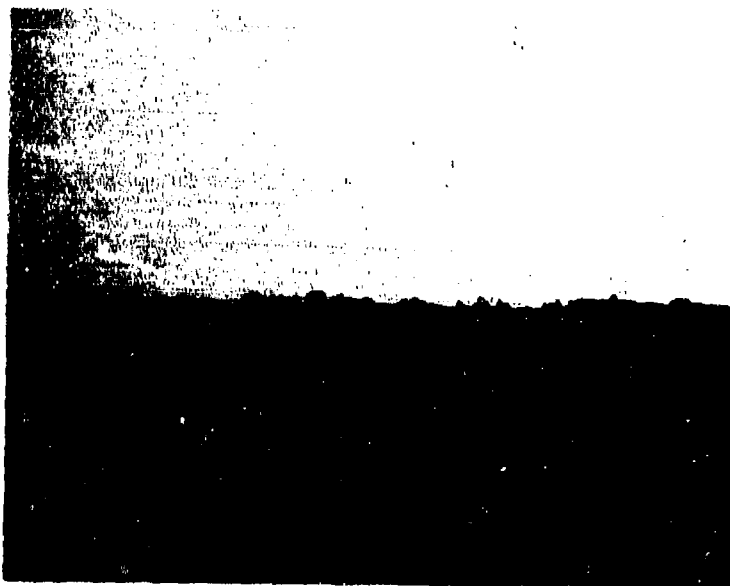


FIGURE 52. Site TTH 1, Ground Photograph.

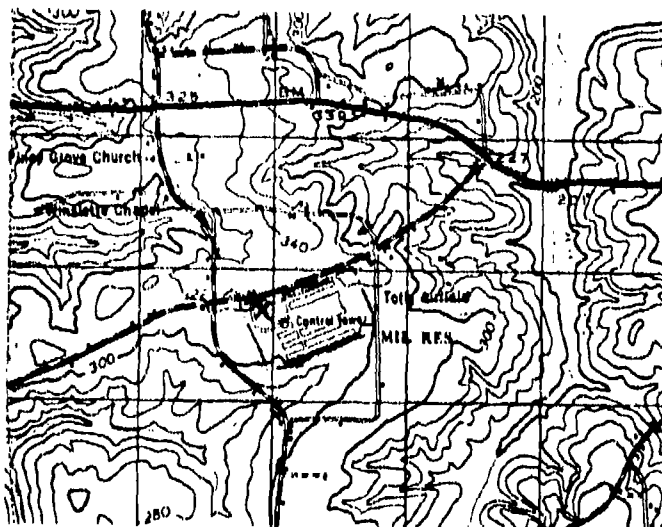


FIGURE 53. Site TTH 1, Topographic Map. Scale is 1:15,000; contour interval is 20 ft.

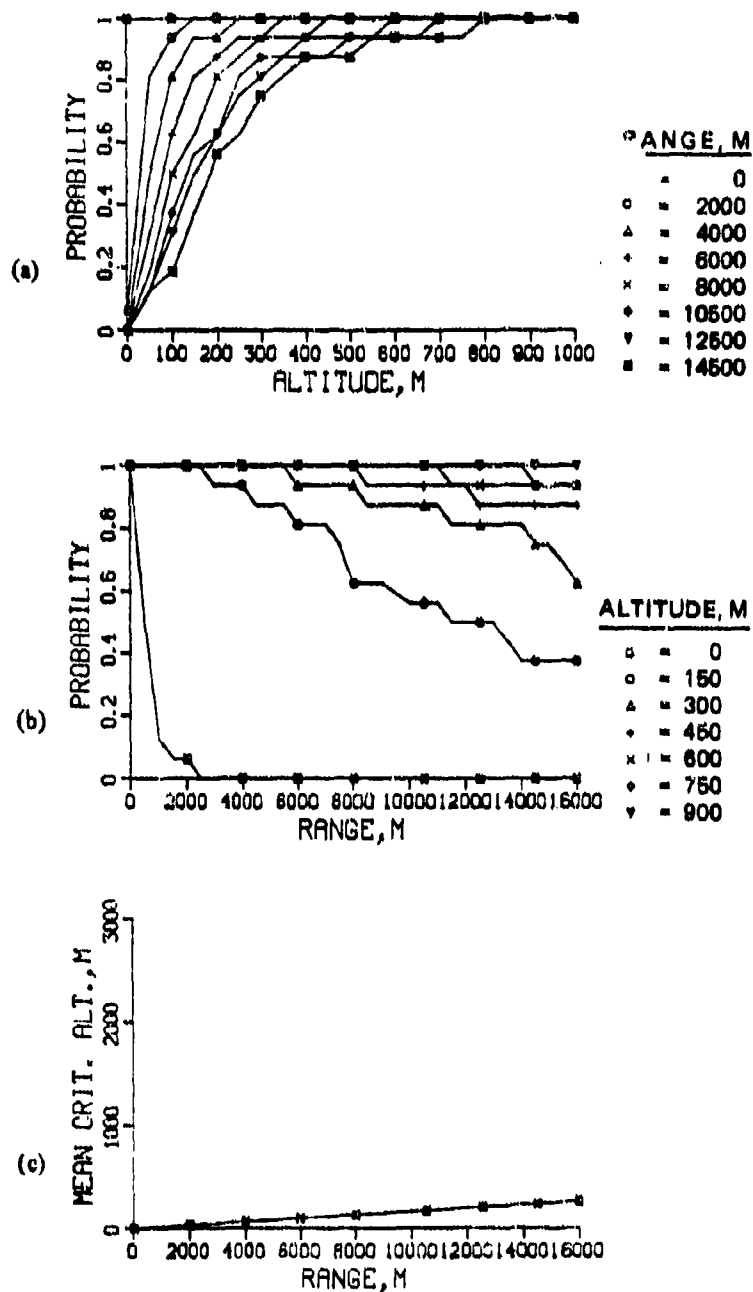


FIGURE 54. Site TTH 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

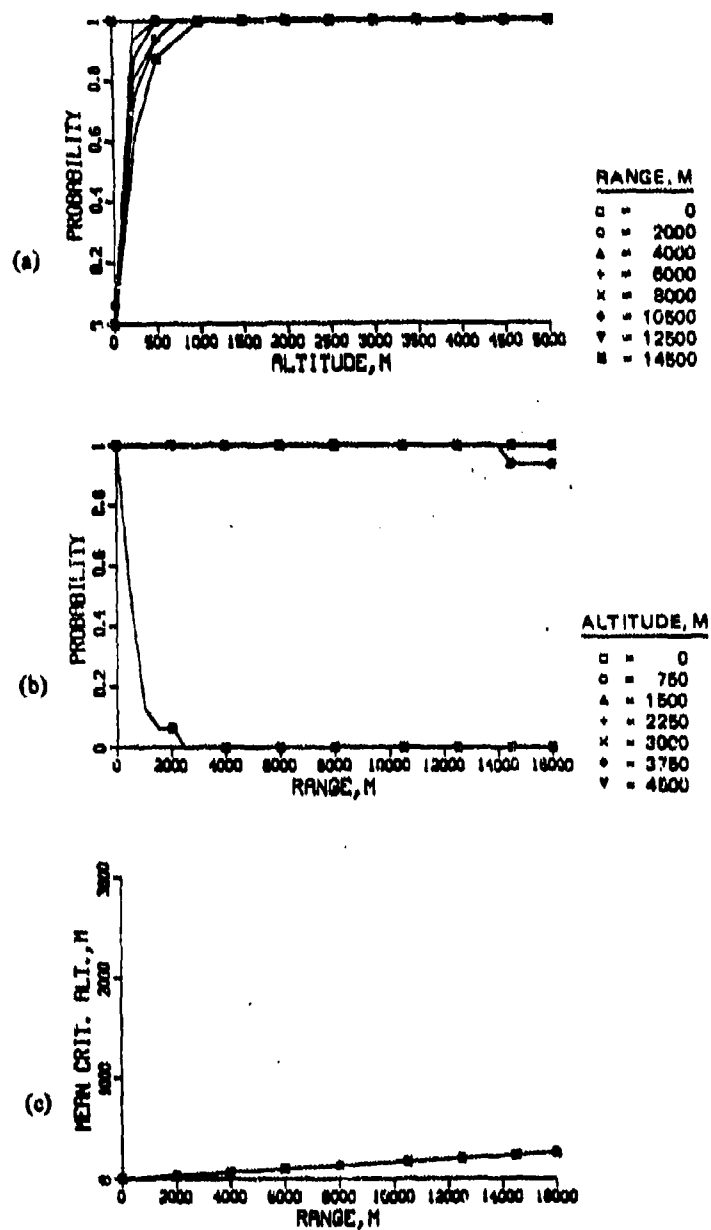


FIGURE 55. Site TTH 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

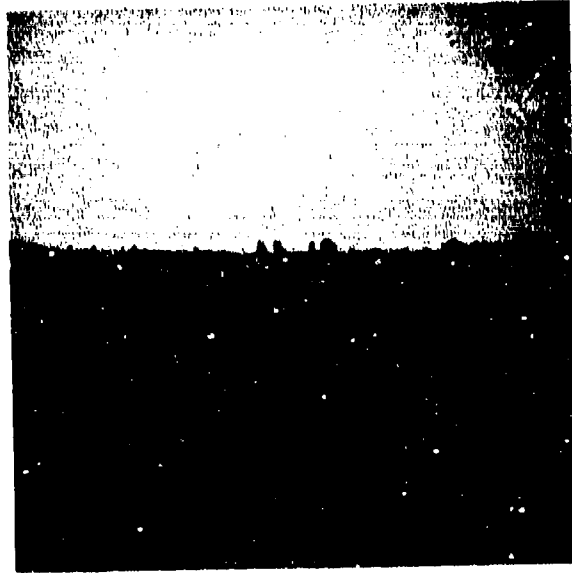


FIGURE 56. Site TTH 2, Ground Photograph.

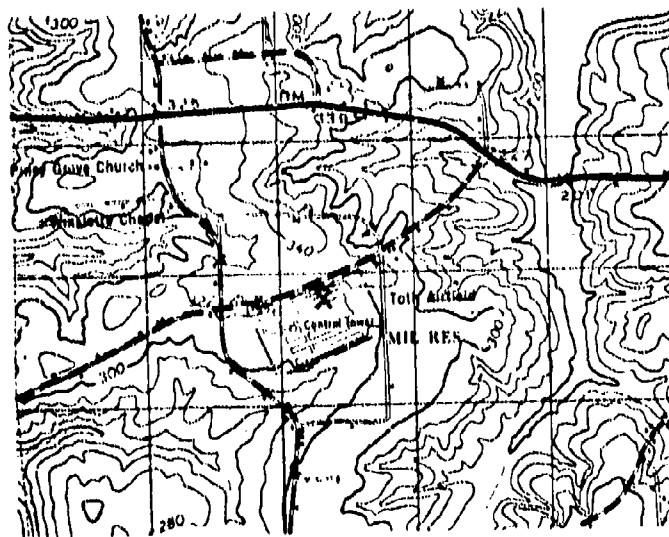


FIGURE 57. Site TTH 2, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

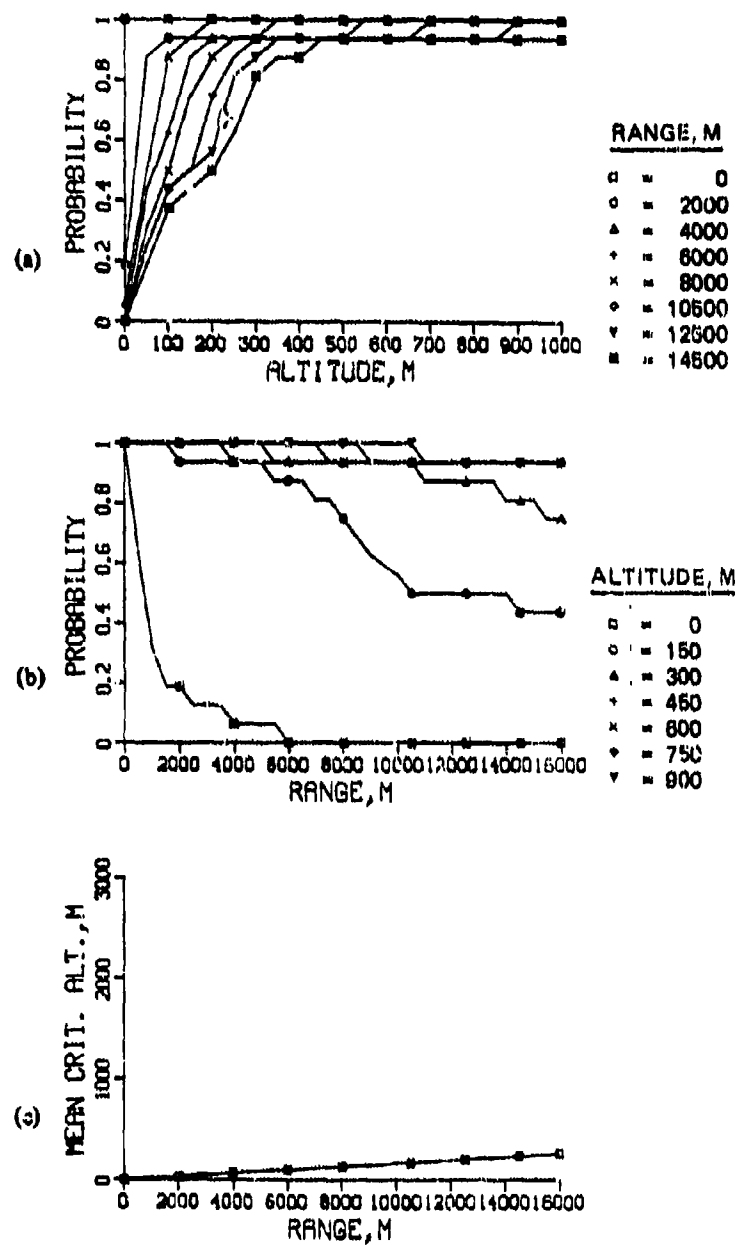


FIGURE 58. Site TTH 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

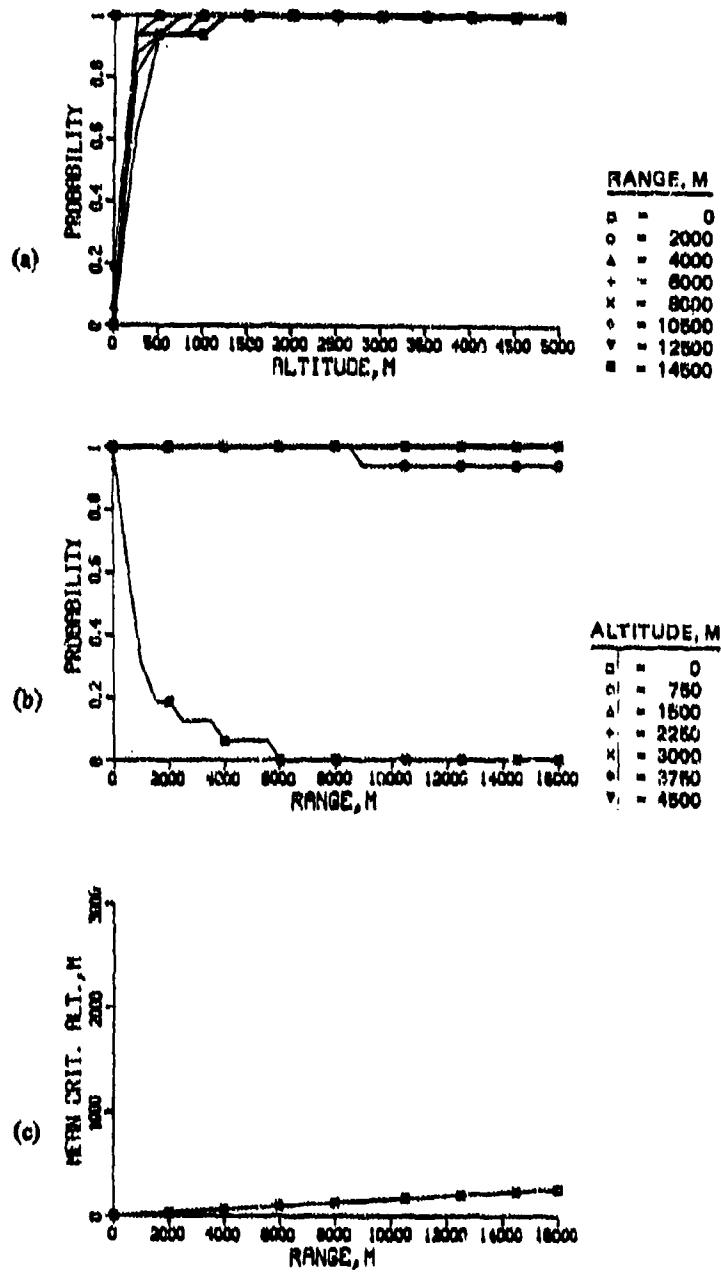


FIGURE 59. Site TTH 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 60. Site HB 1, Ground Photograph.

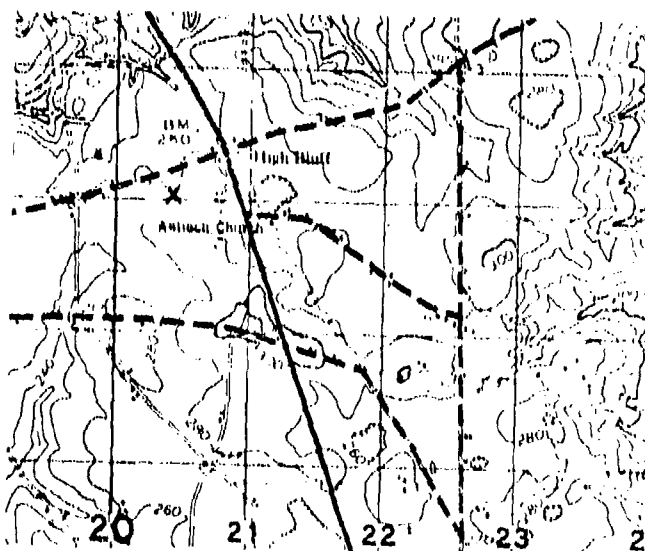


FIGURE 61. Site HB 1, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

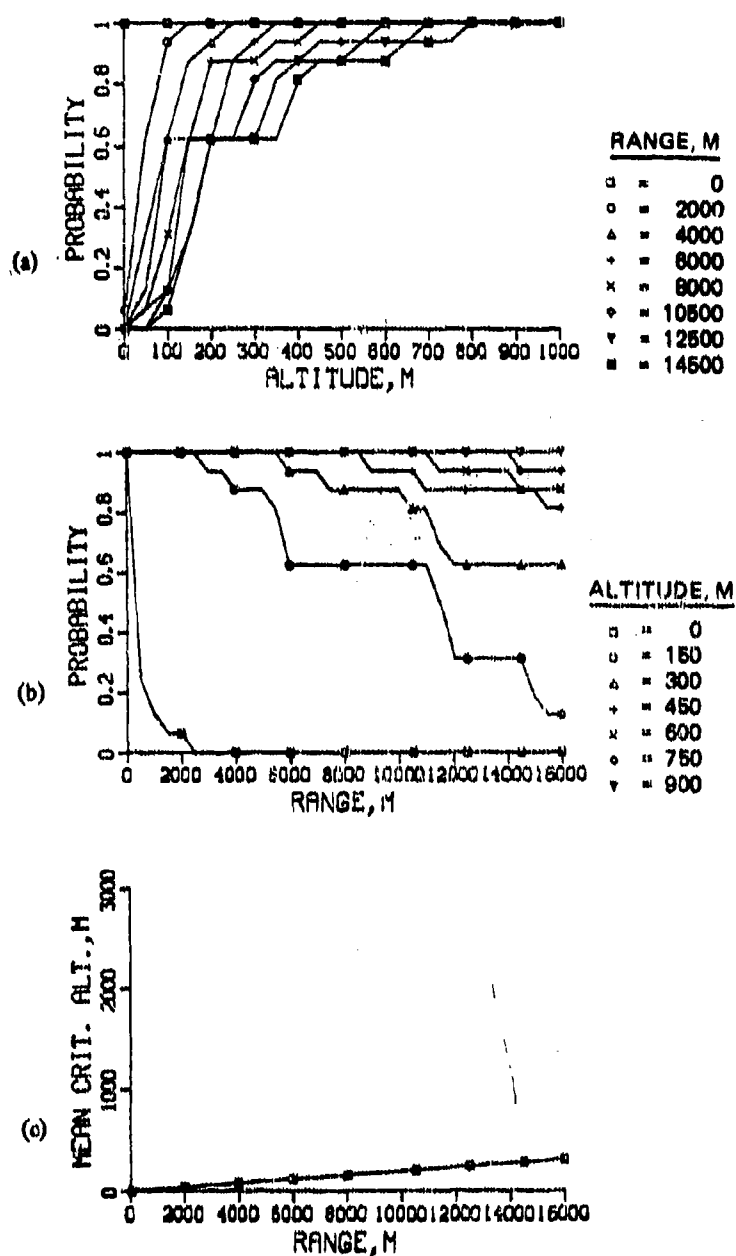


FIGURE 62. Site HB 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

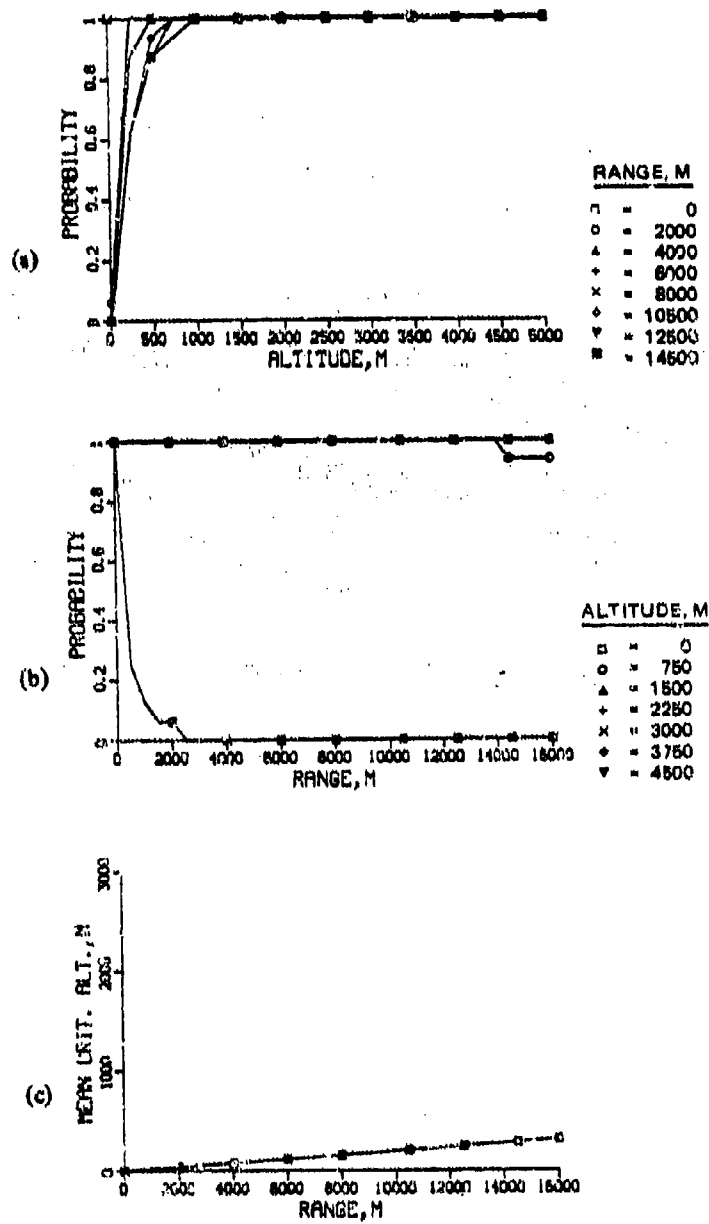


FIGURE 63. Site HB 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 64. Site HF 1, Ground Photograph.

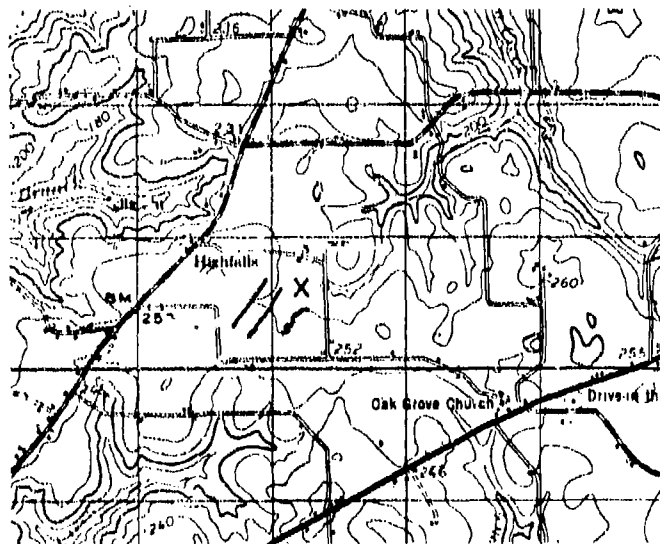


FIGURE 65. Site HF 1, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

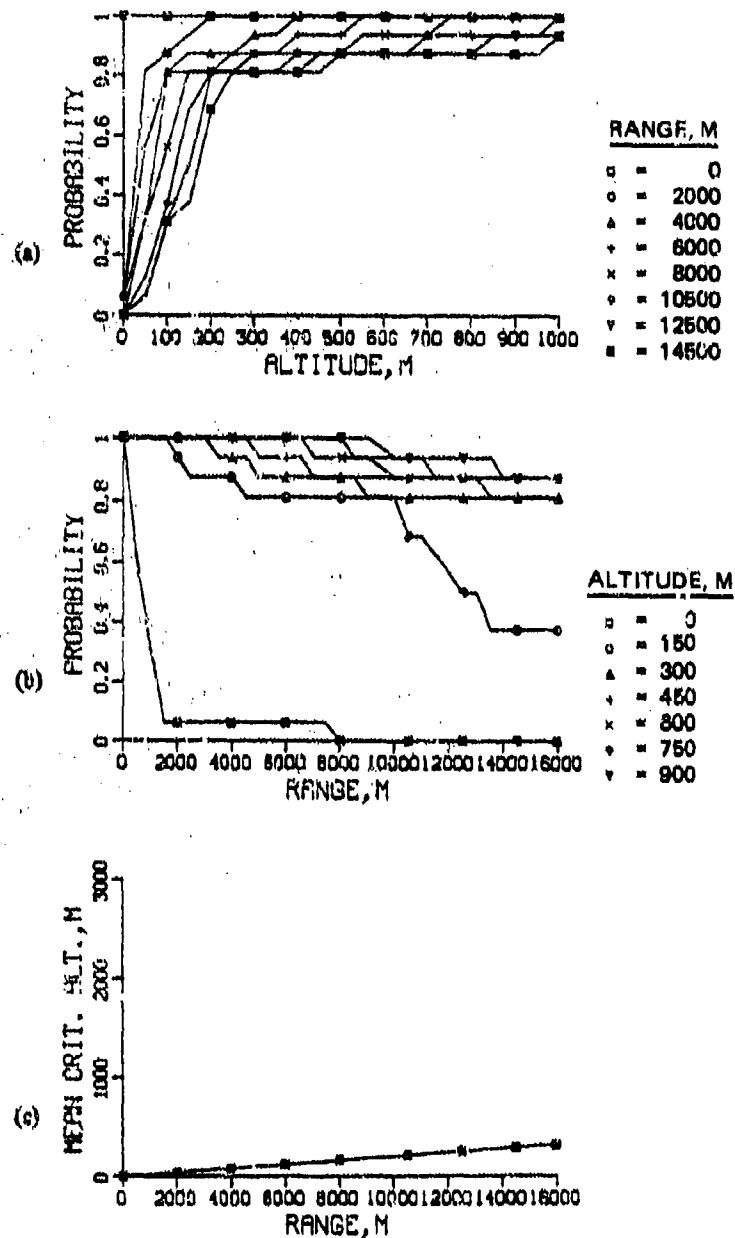


FIGURE 66. Site HF 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

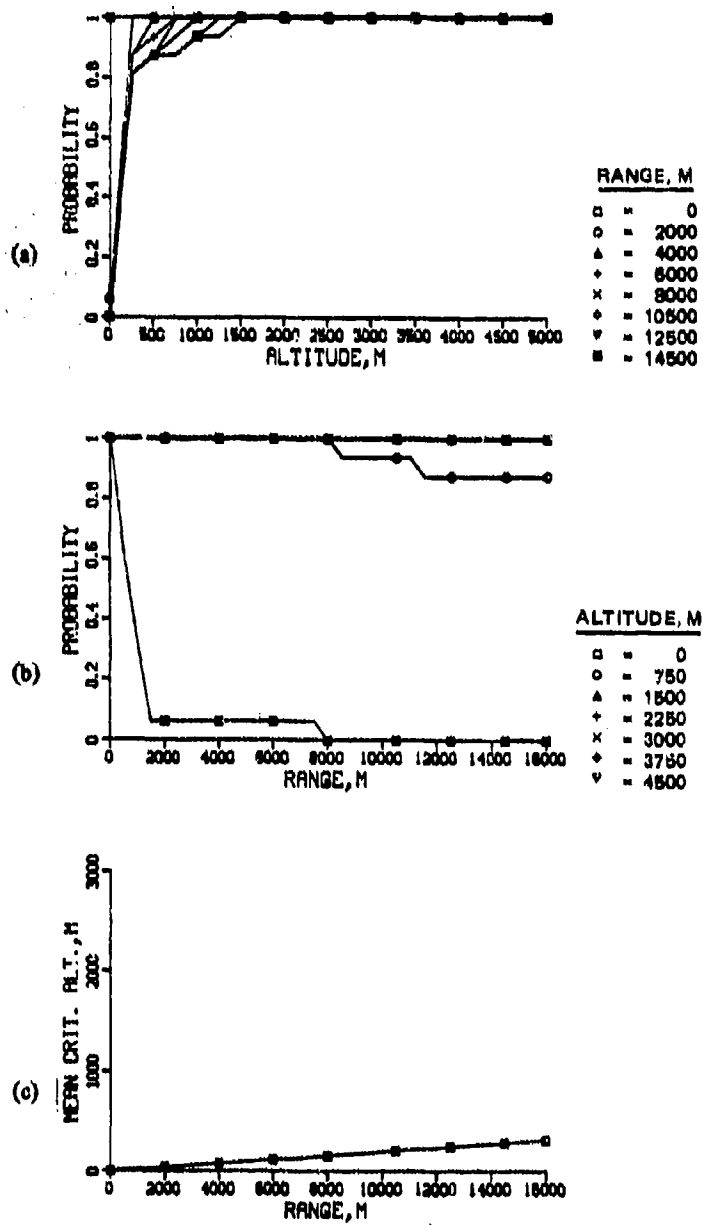


FIGURE 67. Site HF 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

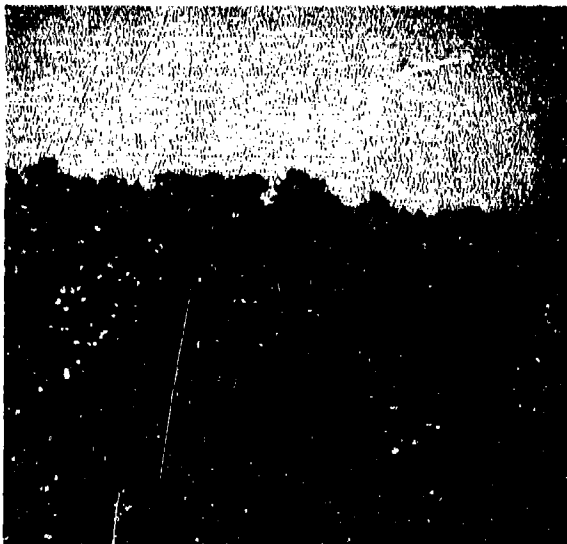


FIGURE 68. Site ALN, Ground Photograph.

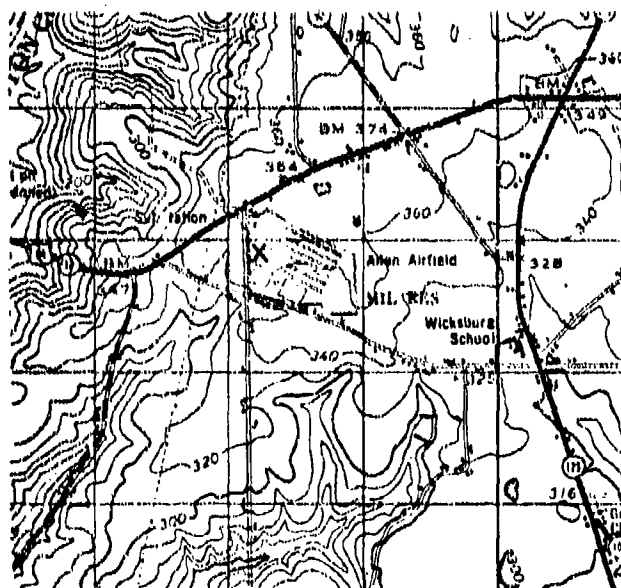


FIGURE 69. Site ALN, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

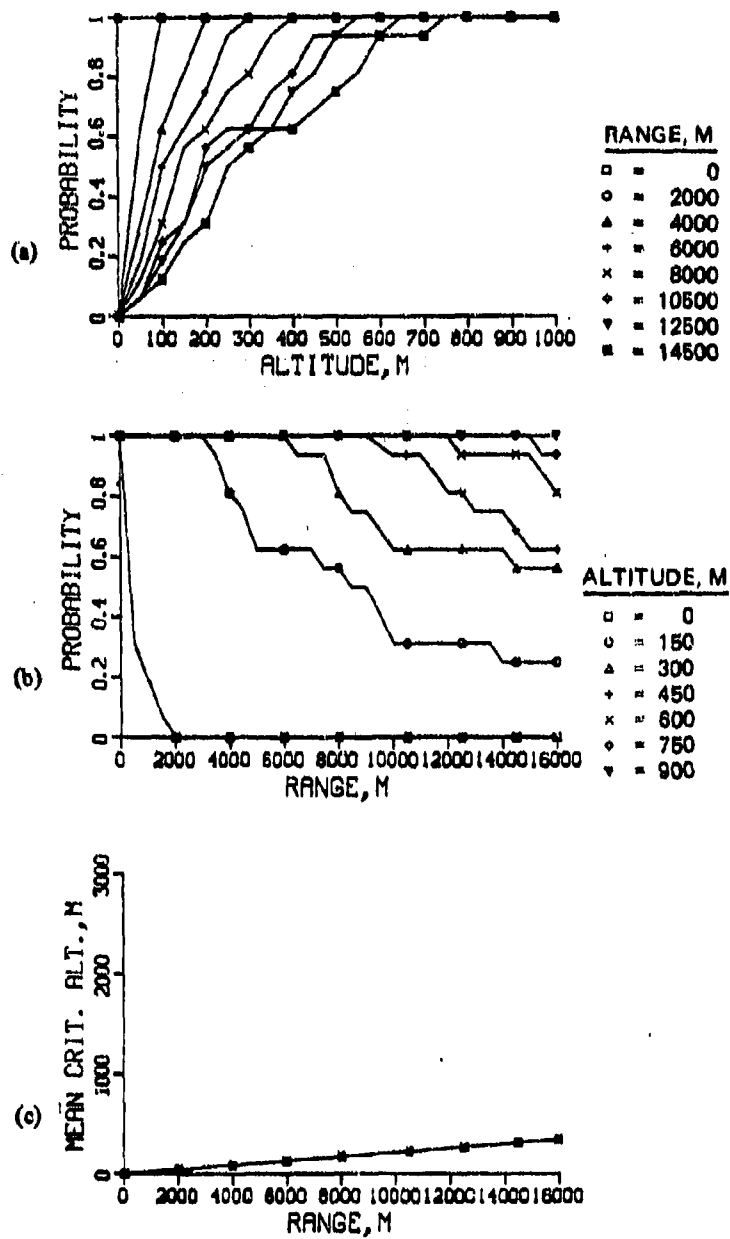


FIGURE 70. Site ALN: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

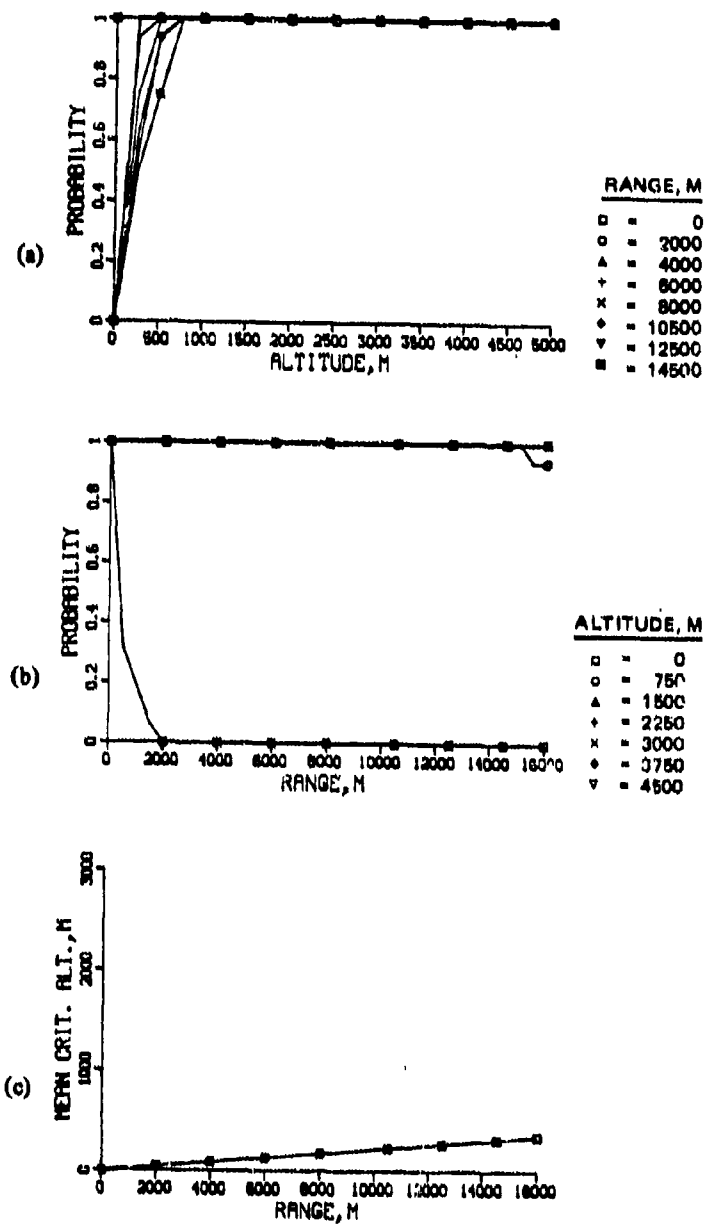


FIGURE 71. Site ALN: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

TERRAIN/VEGETATION TYPE B

Description: Desert, fairly smooth, with scattered bushes.

Data available: Aerial photographs, ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs (see Figures 72 through 93).

Number of sites surveyed: Five.

Site designations: Y 1, Y 2, Y 3, Y 4, RDM 3.

Approximate number of LOS measurements: 100.

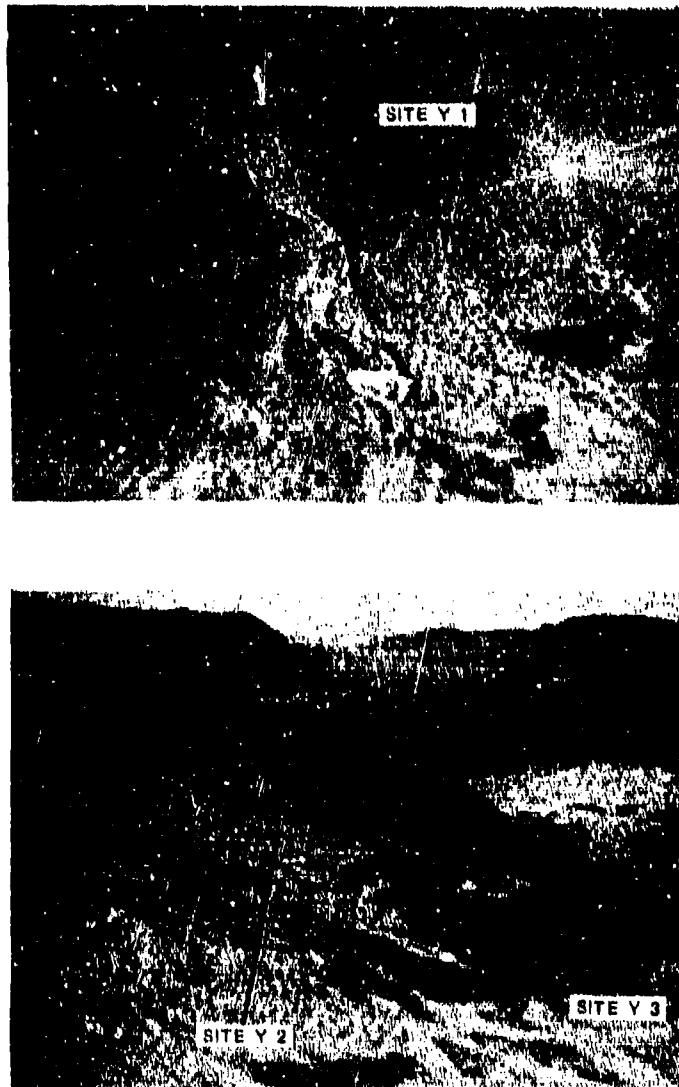


FIGURE 72. Aerial Photographs of Sites Used To Measure Terrain/Vegetation Type B, Showing Sites Y 1, Y 2, and Y 3.

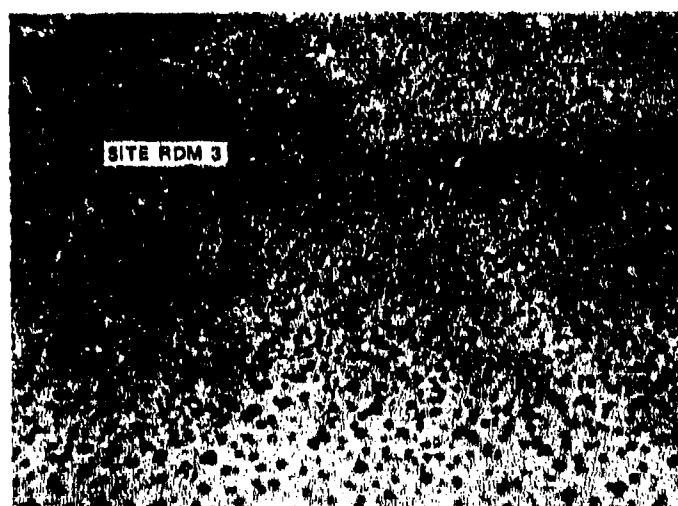
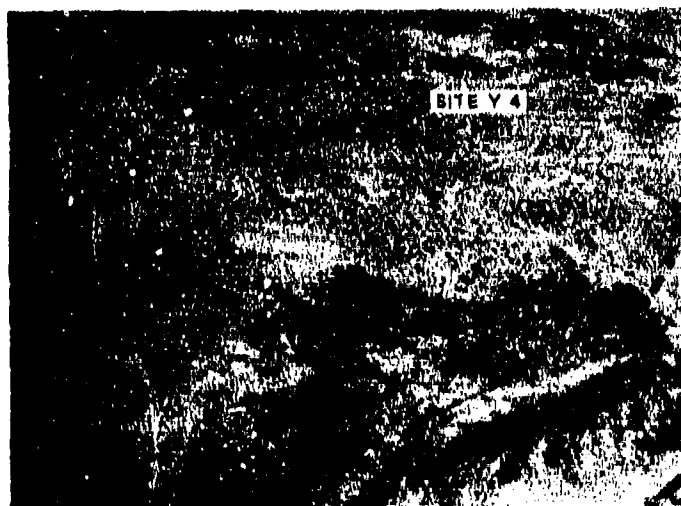


FIGURE 73. Aerial Photographs of Sites Used To Measure Terrain/Vegetation Type B, Showing Sites Y 4 and RDM 3.

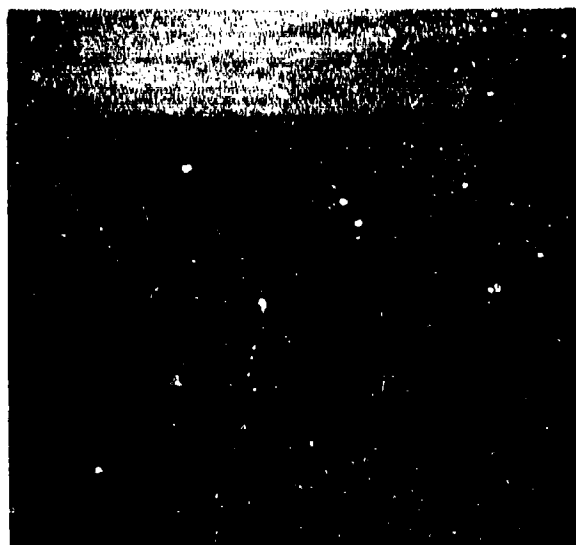


FIGURE 74. Site Y 1, Ground Photograph.

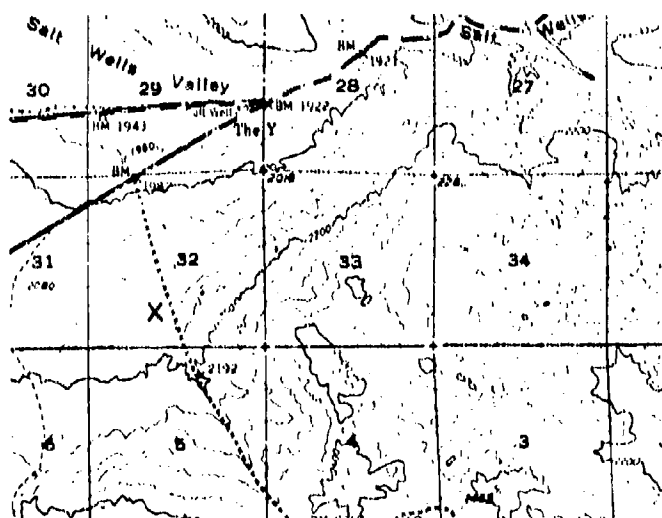


FIGURE 75. Site Y 1, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

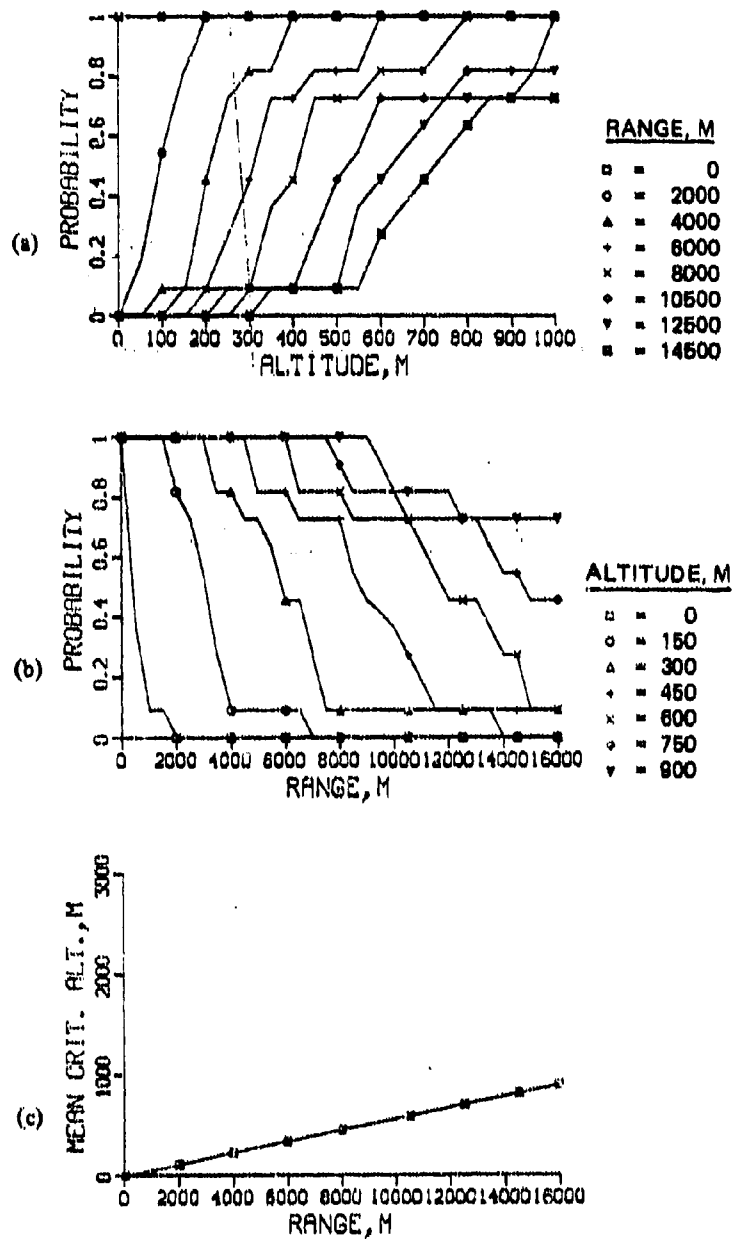


FIGURE 76. Site Y 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

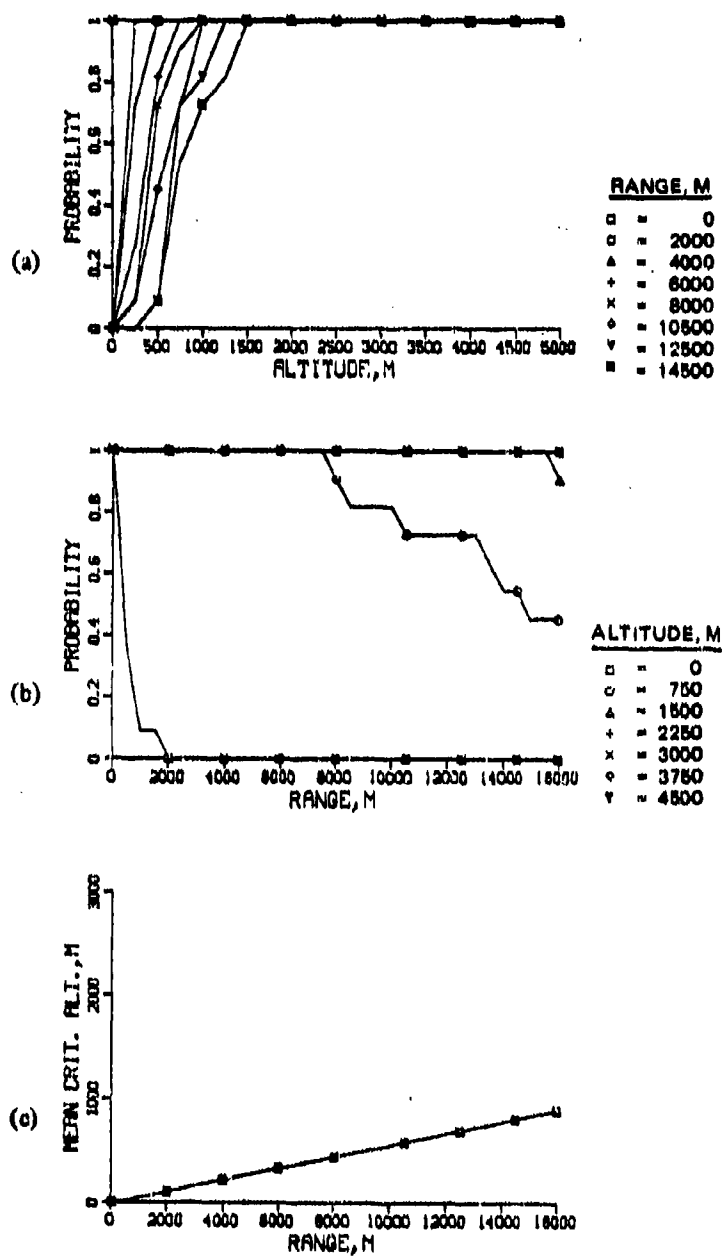


FIGURE 77. Site Y 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 78. Site Y 2, Ground Photograph.

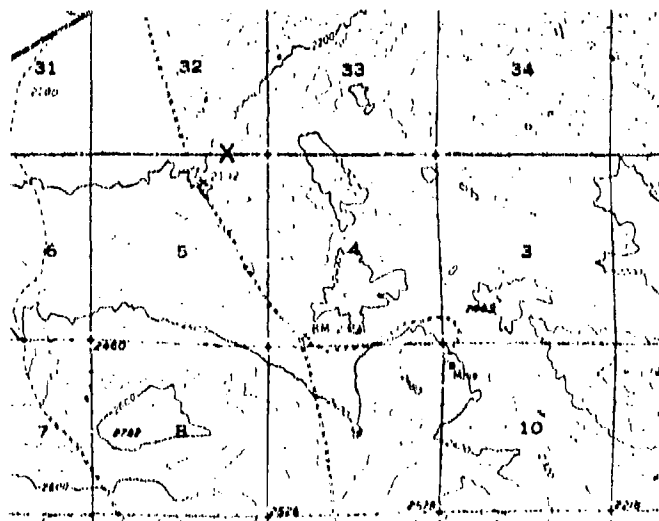


FIGURE 79. Site Y 2, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

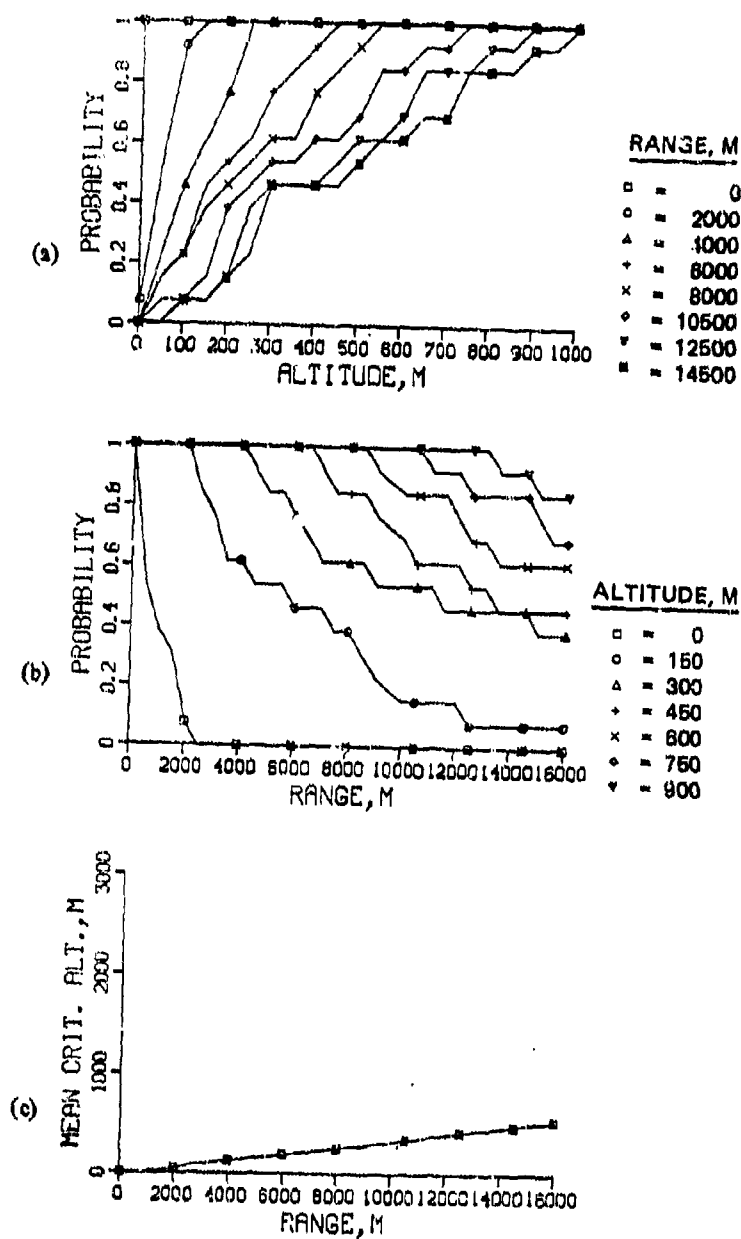


FIGURE 80. Site Y 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

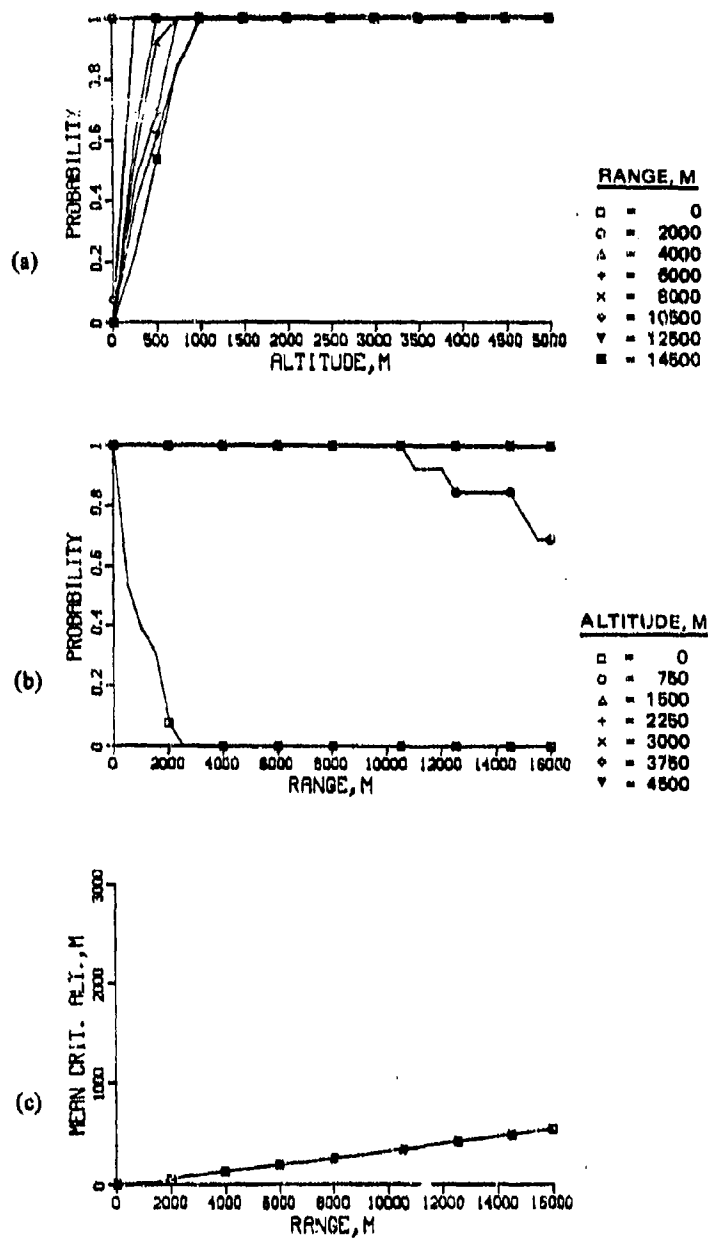


FIGURE 81. Site Y 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 82. Site Y 3, Ground Photograph.

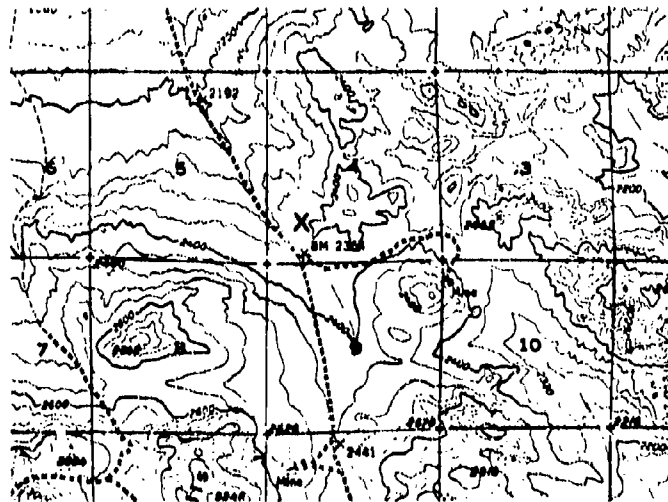


FIGURE 83. Site Y 3, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

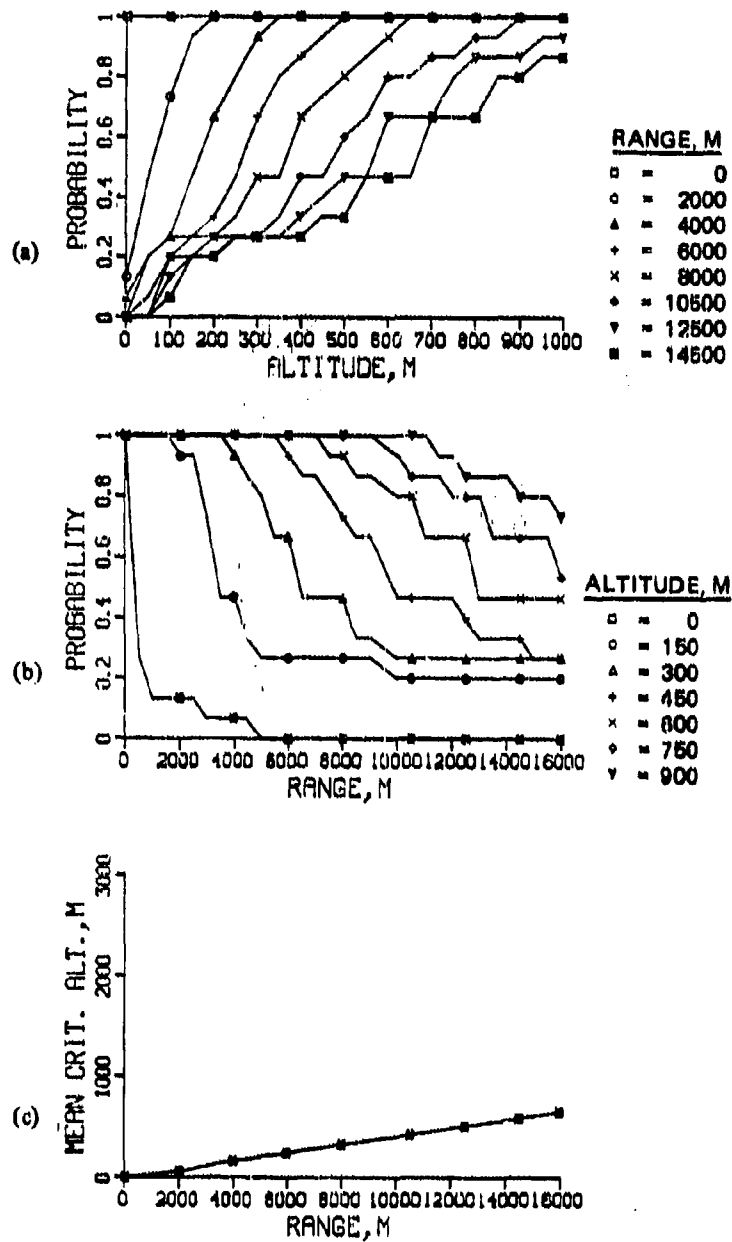


FIGURE 84. Site Y 3: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

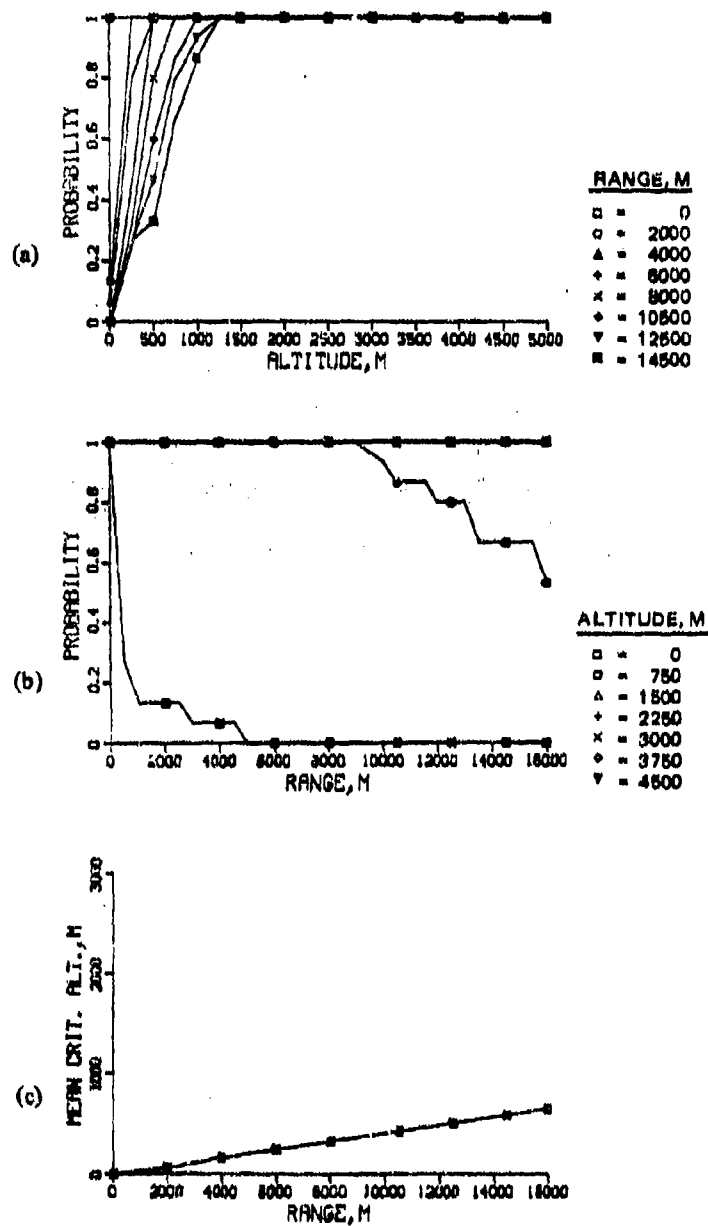


FIGURE 85. Site Y 3: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 86. Site Y 4, Ground Photograph.

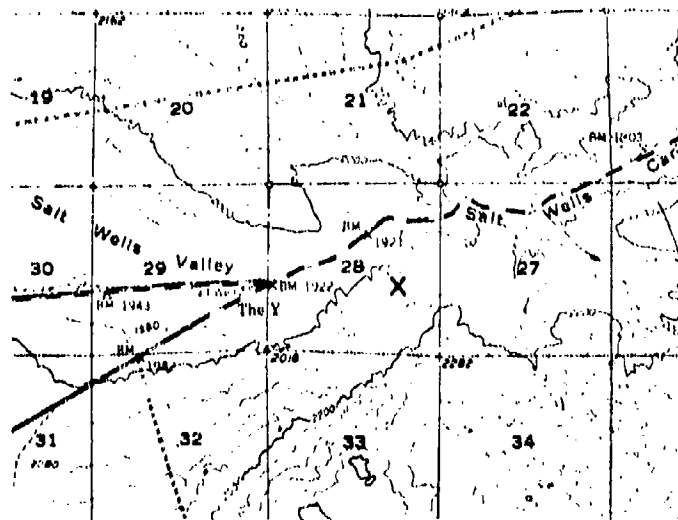


FIGURE 87. Site Y 4, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

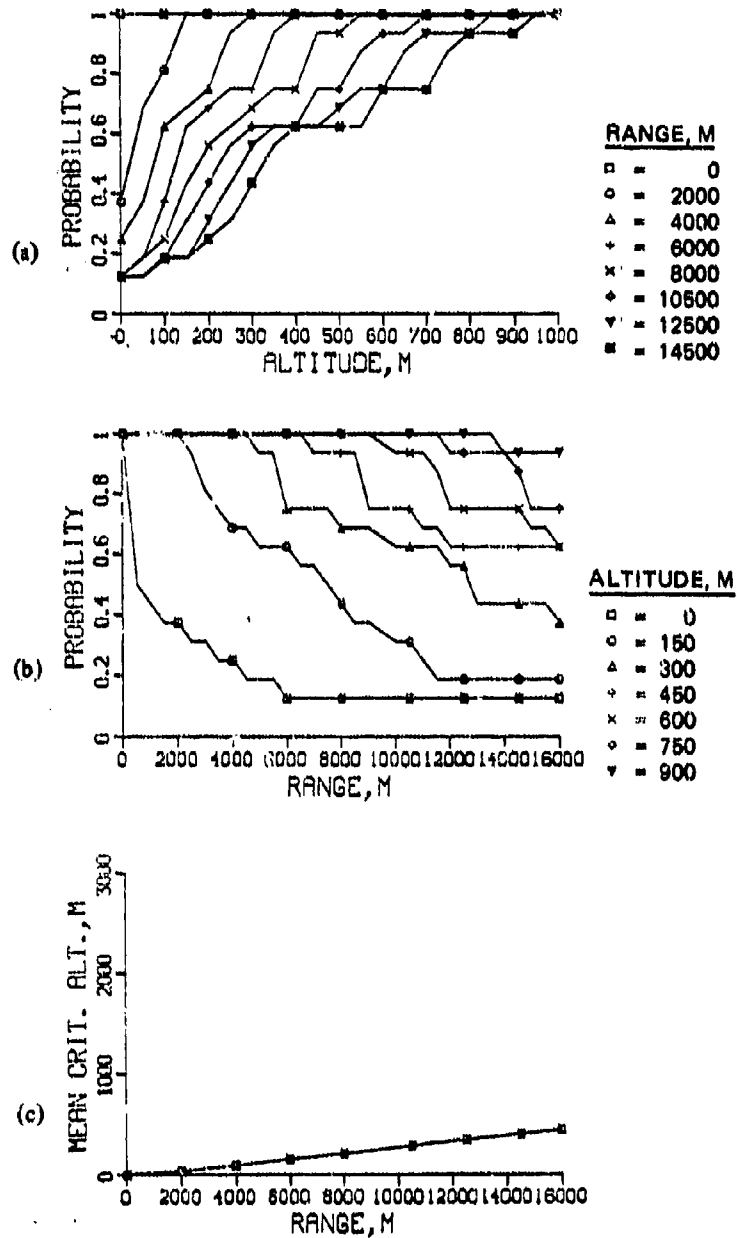


FIGURE 88. Site Y 4: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

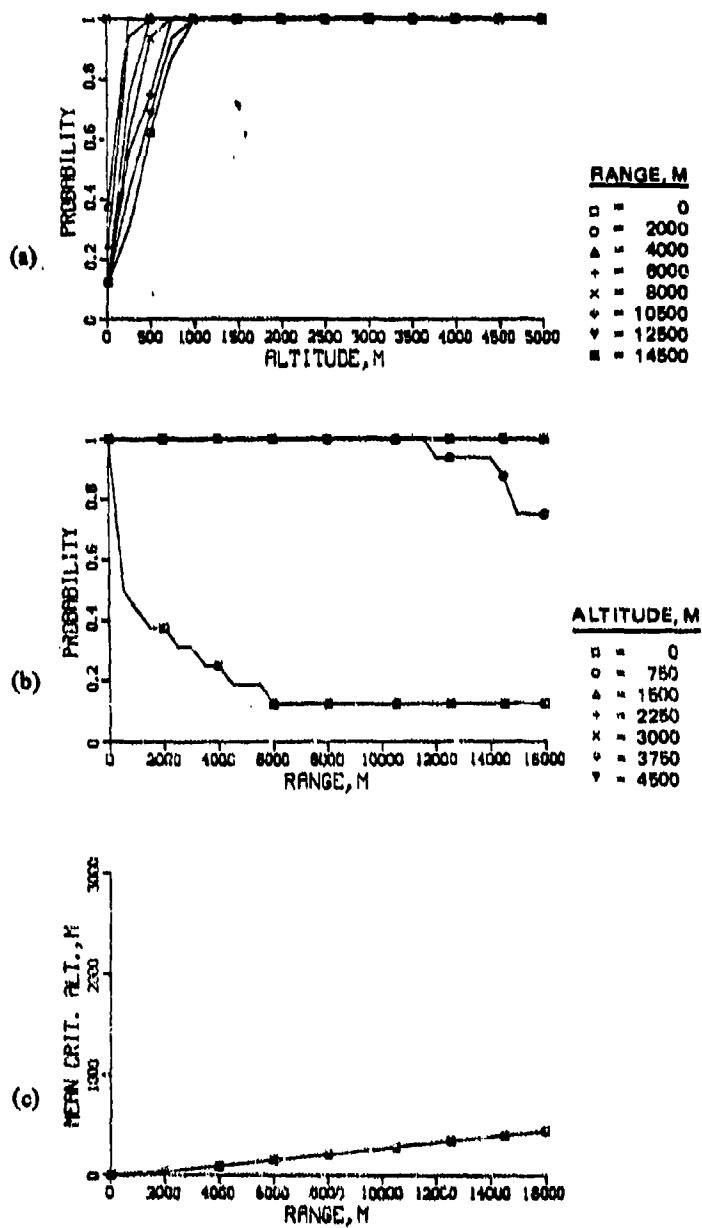


FIGURE 89. Site Y 4: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

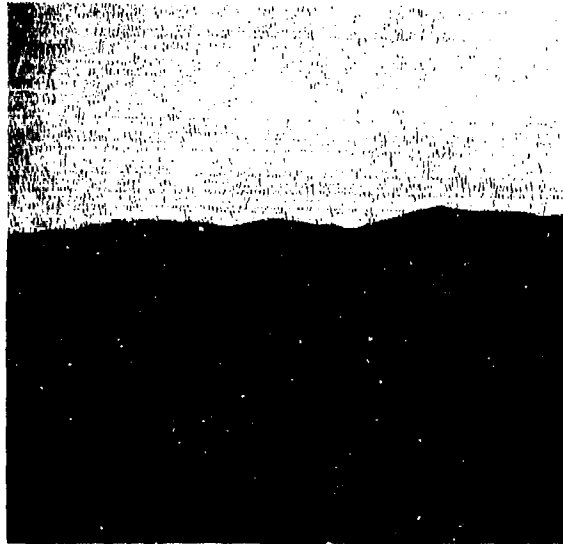


FIGURE 90. Site RDM 3, Ground Photograph.

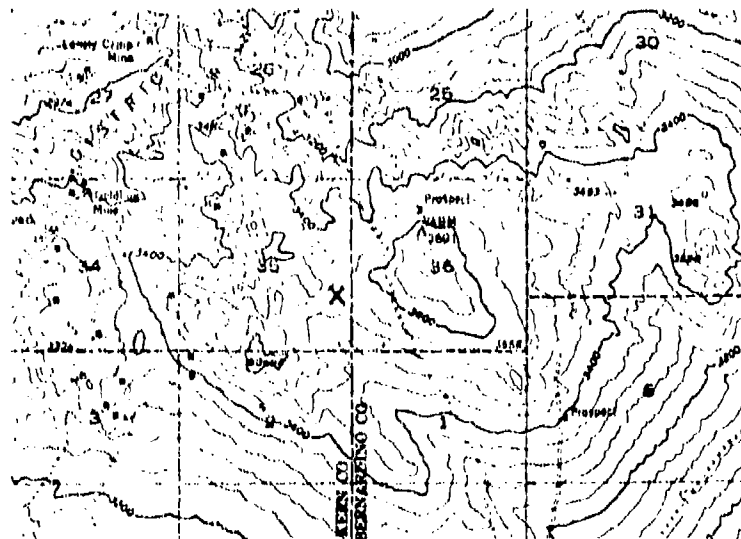


FIGURE 91. Site RDM 3, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

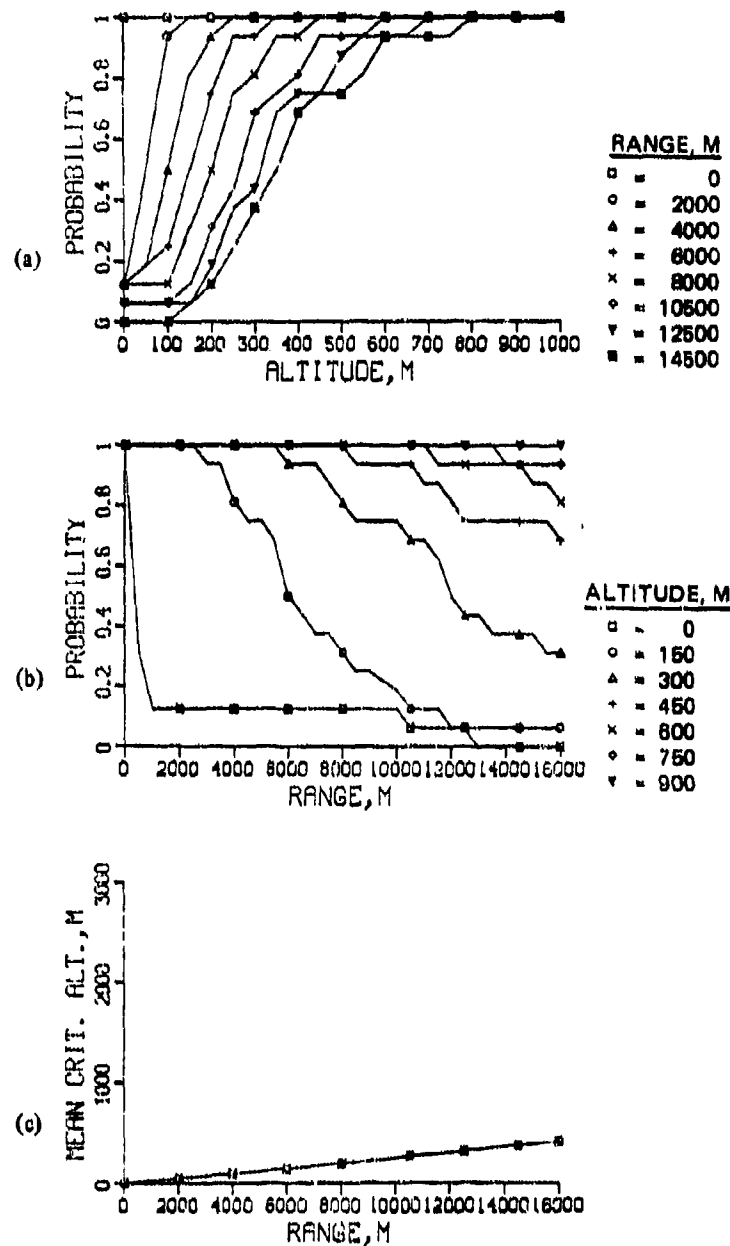


FIGURE 92. Site RDM 3: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

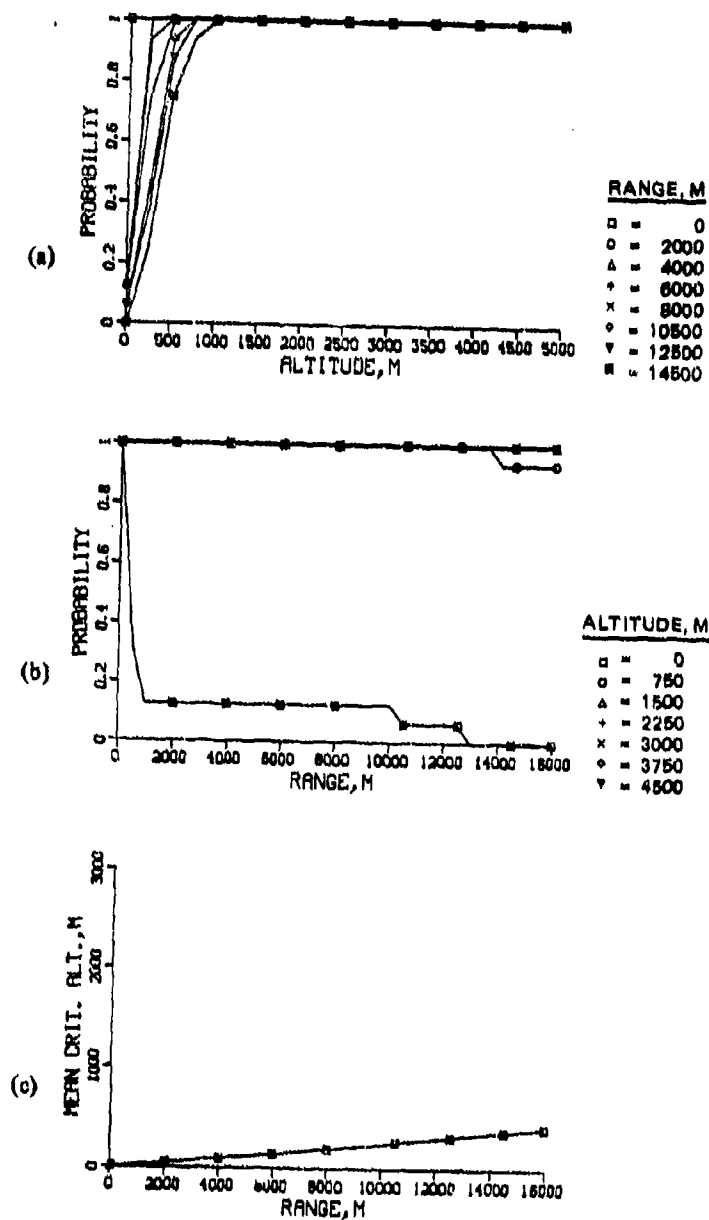


FIGURE 93. Site RDM 3: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

TERRAIN/VEGETATION TYPE C

Description: Farmland, rolling, with thick forests close in.

Data available: Ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs (see Figures 94 through 105).

Number of sites surveyed: Three.

Site designations: CHE 1, DH 1, DDE.

Approximate number of LOS measurements: 60.



FIGURE 94. Site CHE 1, Ground Photograph.

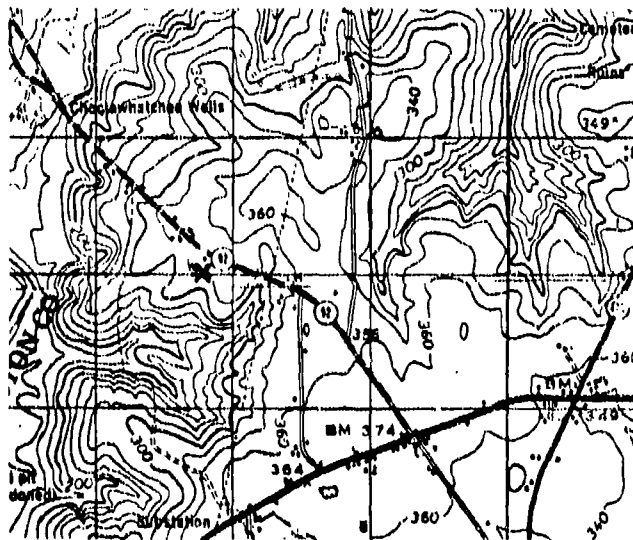


FIGURE 95. Site CHE 1, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

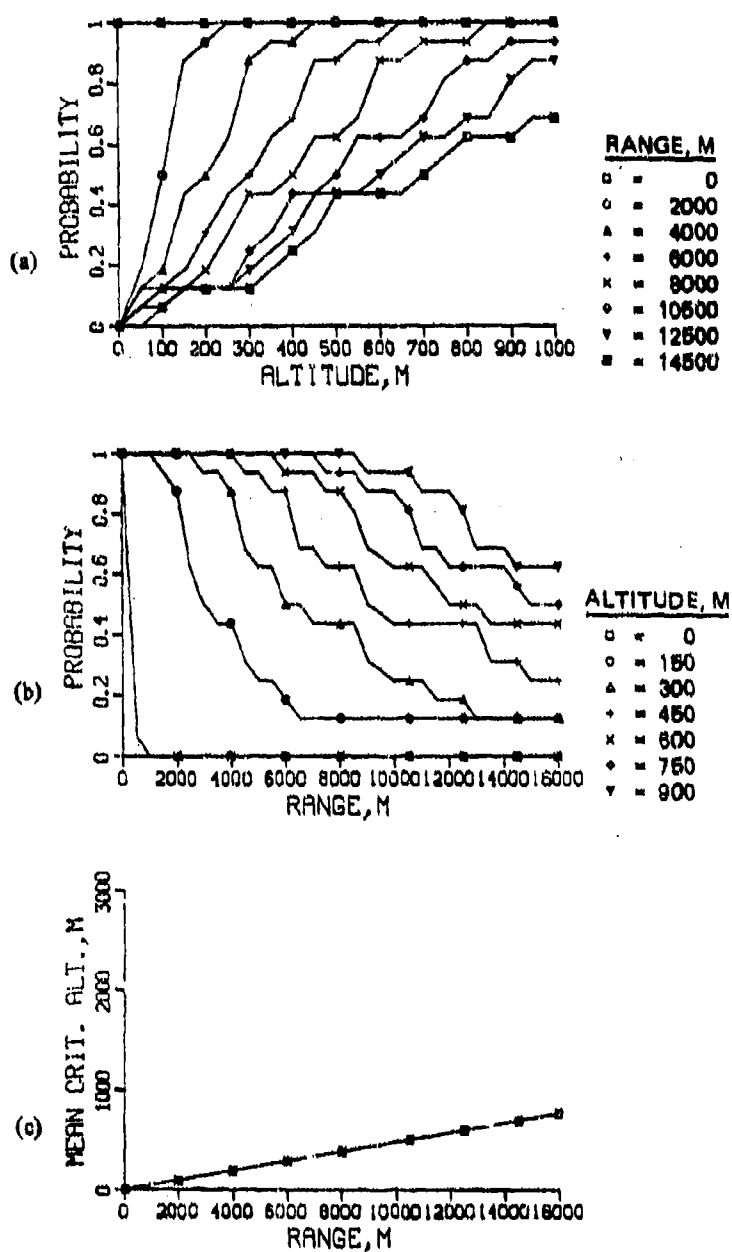


FIGURE 96. Site CHE 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

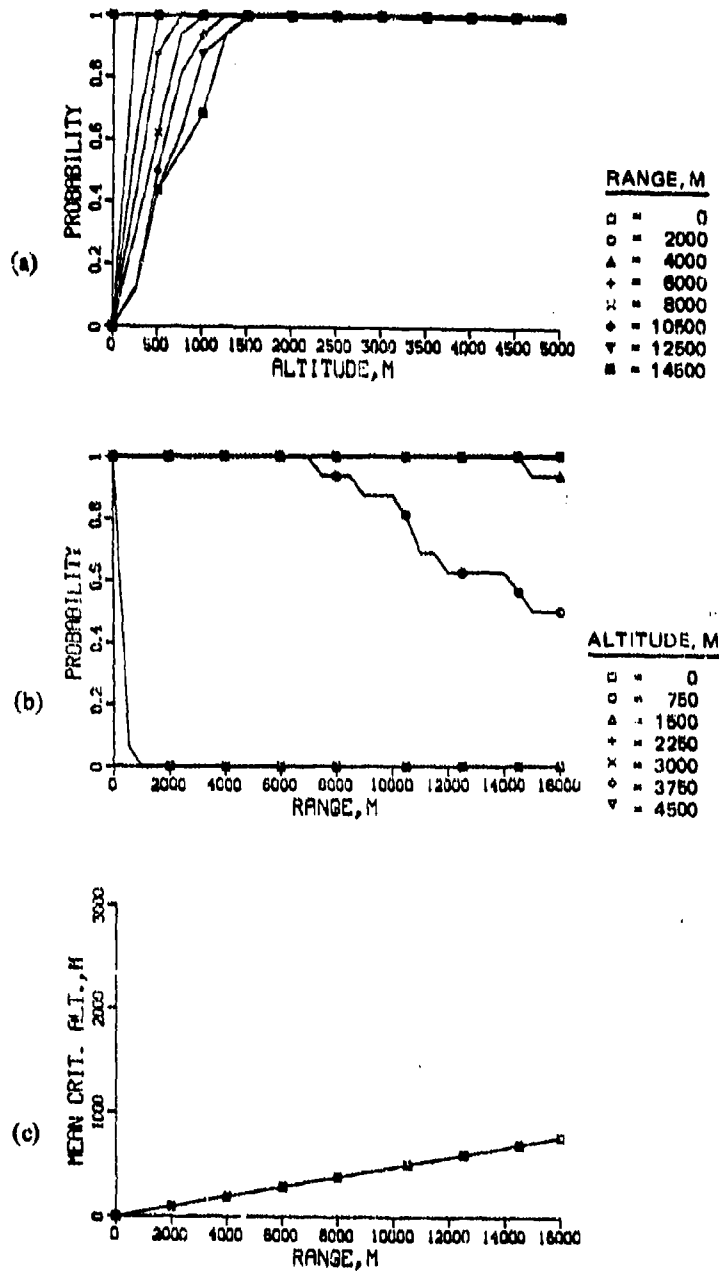


FIGURE 97. Site CHE 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 98. Site DH 1, Ground Photograph.

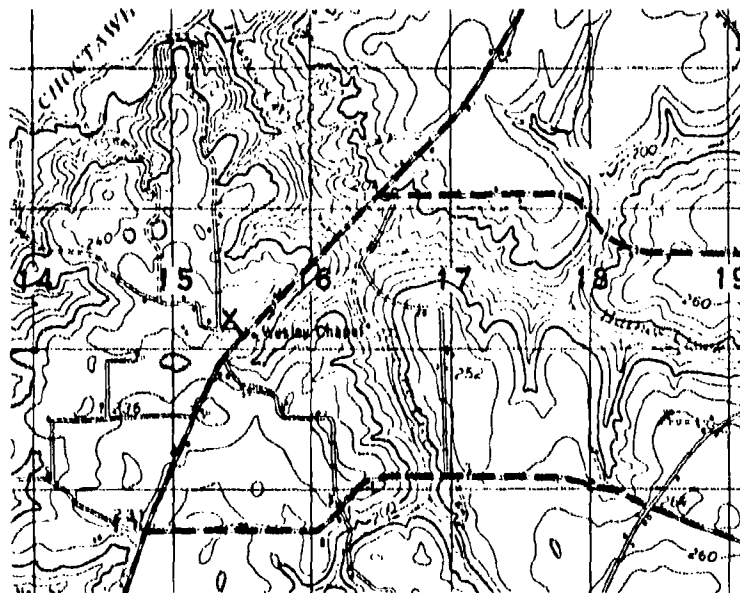


FIGURE 99. Site DH 1, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

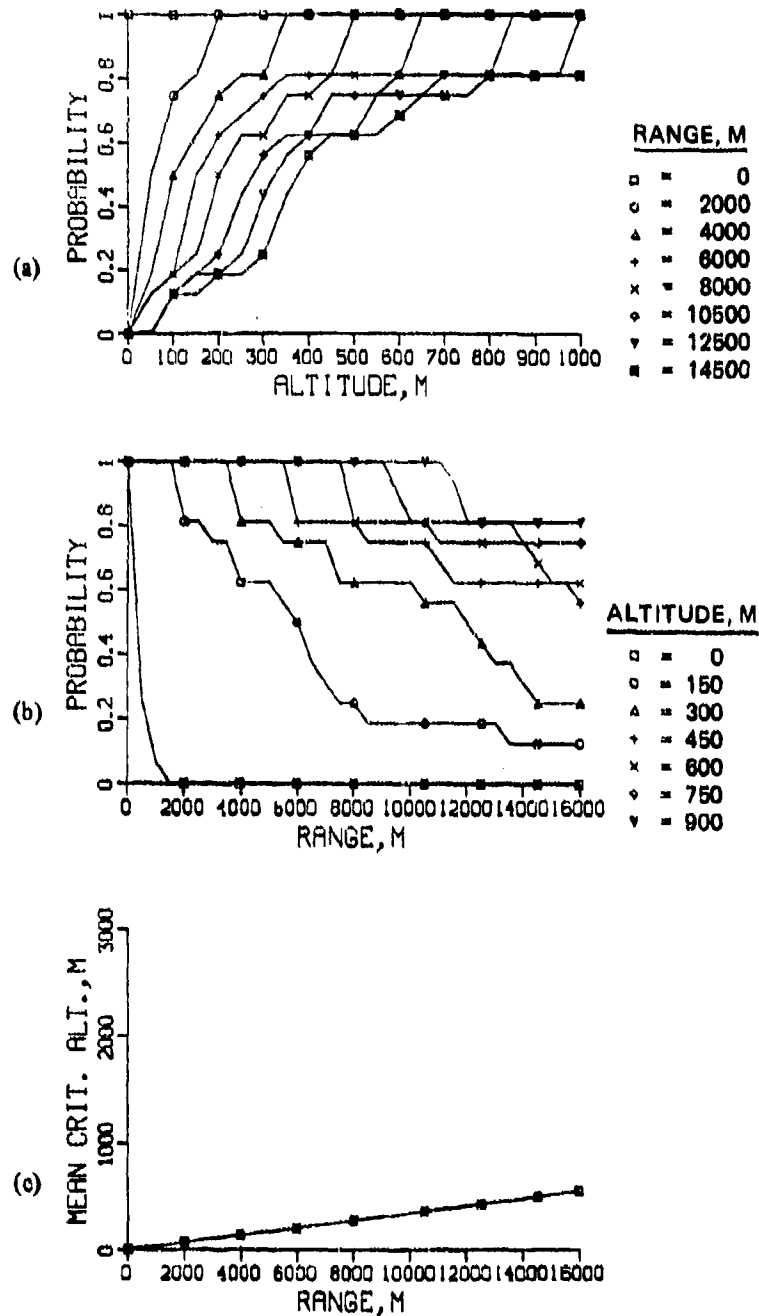


FIGURE 100. Site DH 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

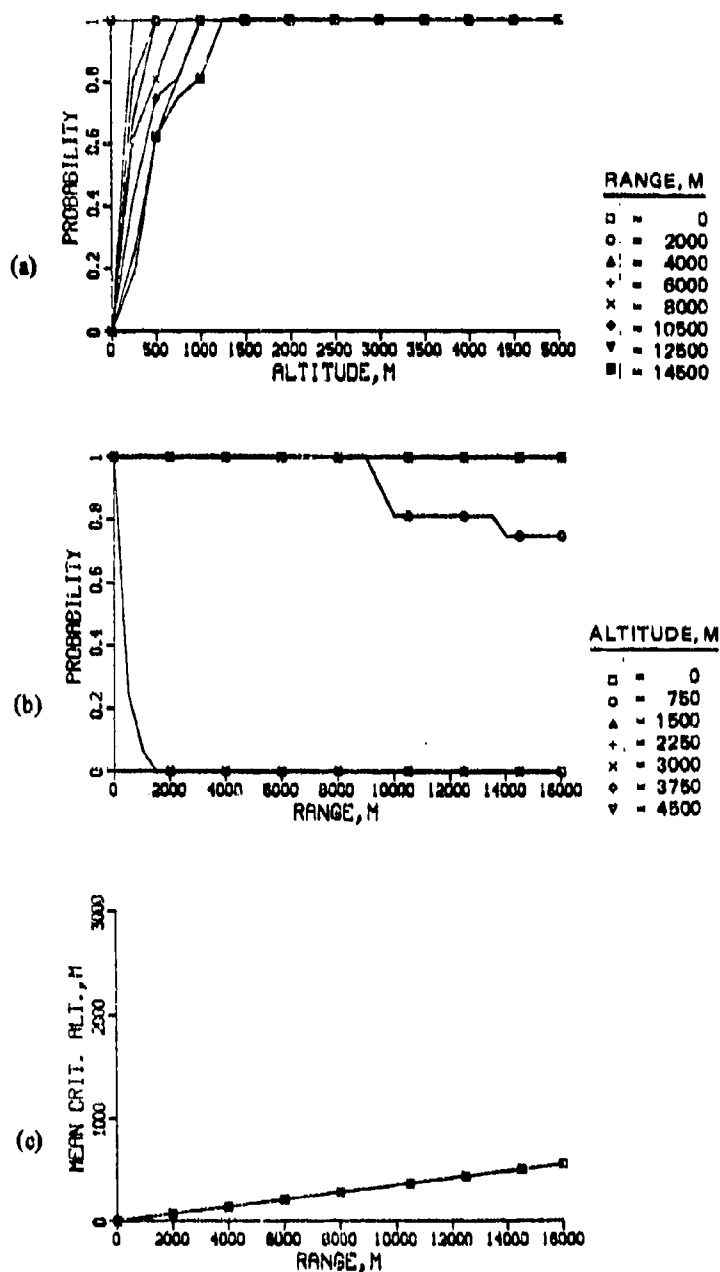


FIGURE 101. Site DH 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 102. Site DDE, Ground Photograph.

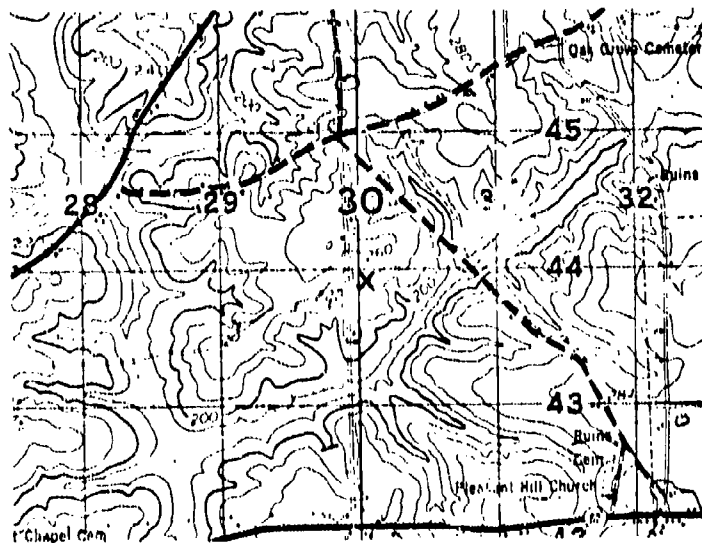


FIGURE 103. Site DDE, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

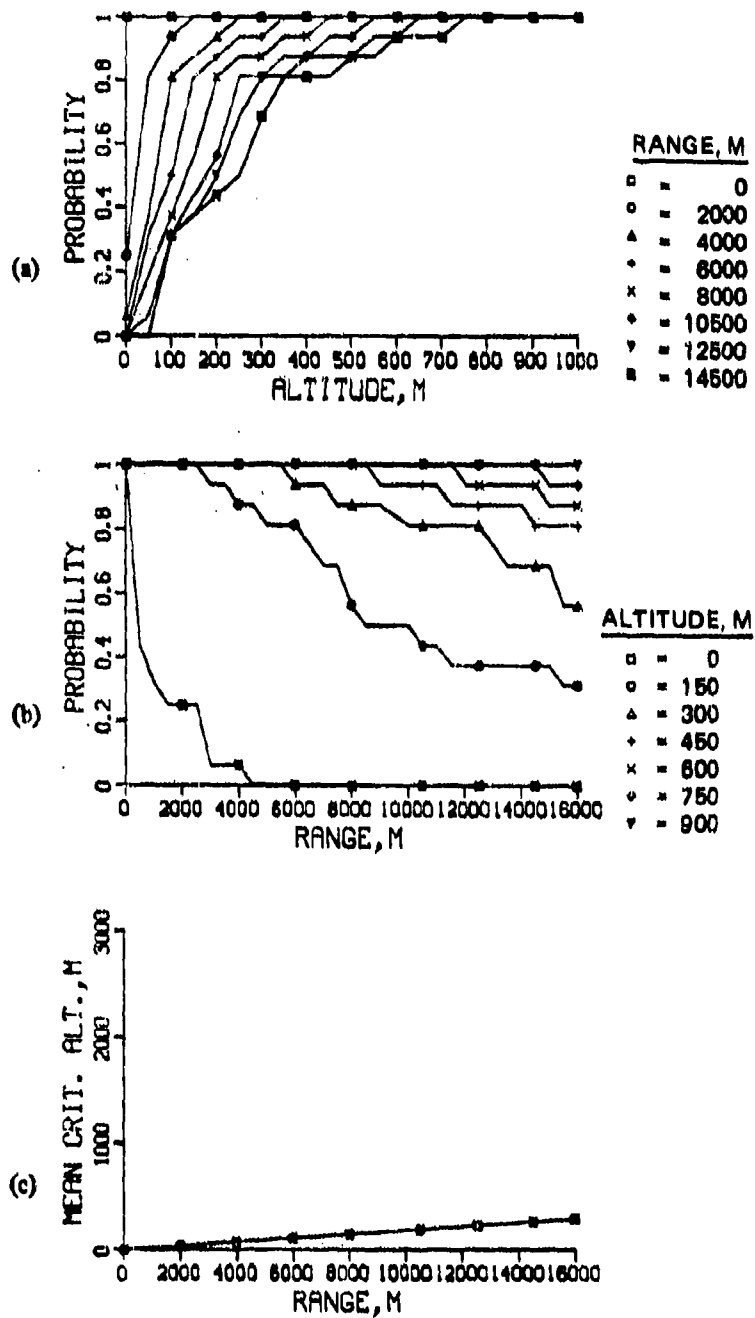


FIGURE 104. Site DDE: Probability of LOS as a Function of (a) Altitude up to 1000 m, to and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

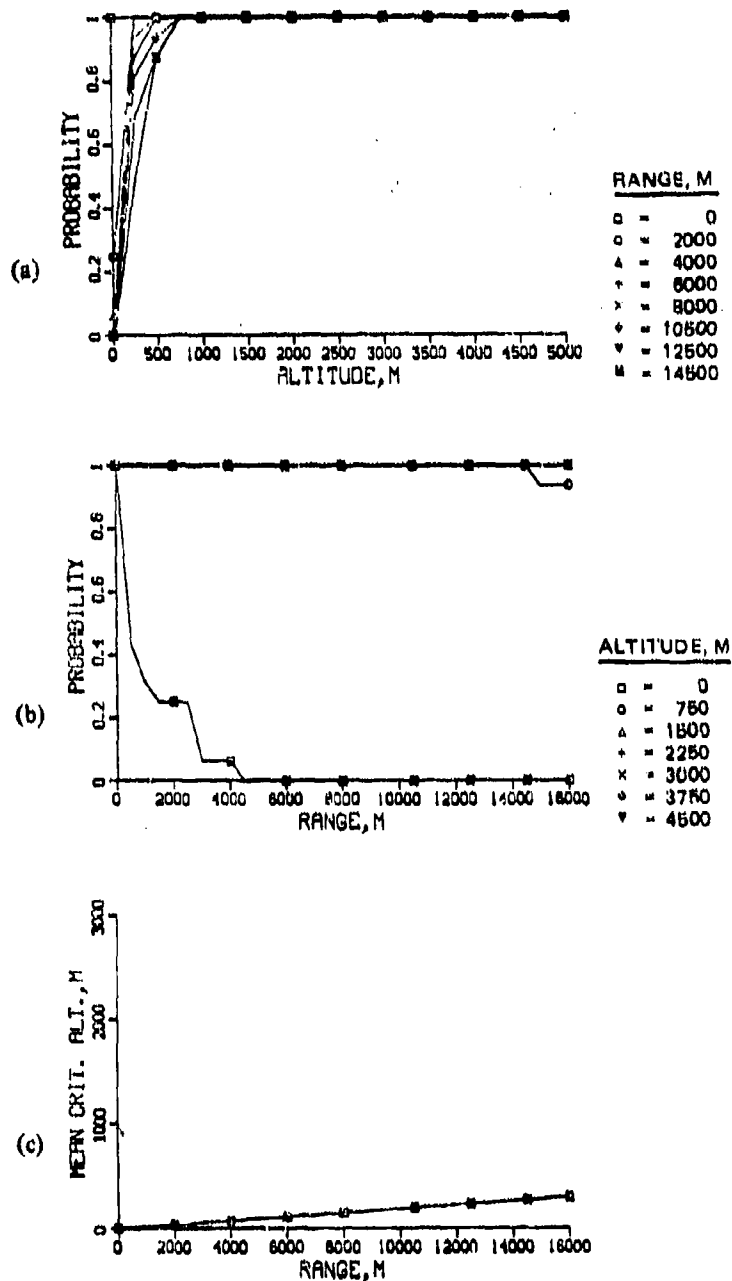


FIGURE 105. Site DDE: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

TERRAIN/VEGETATION TYPE D

Description: Desert, moderately rough, with scattered bushes.
Hills, rolling, with scattered bushes.

Data available: Aerial photographs, ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs, (see Figures 106 through 132).

Number of sites surveyed: Six.

Site designations: MSP 2, RDM 1, WC 1, WC 2, CM 1, CM 2.

Approximate number of LOS measurements: 120.

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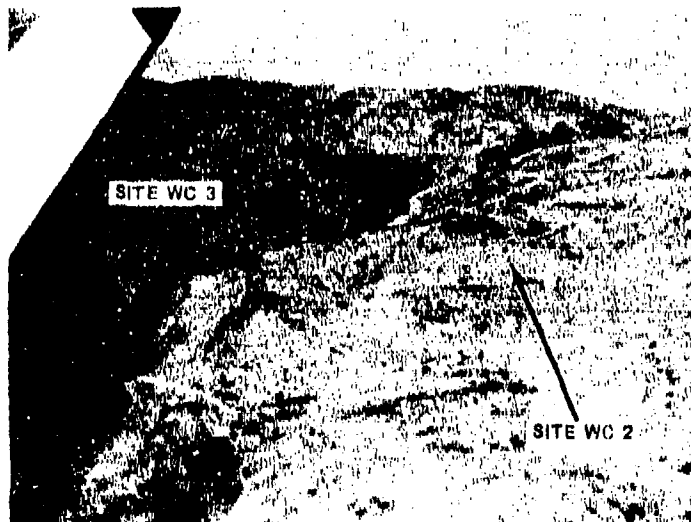


FIGURE 106. Aerial Photographs of Sites Used To Measure Terrain/Vegetation Type D, Showing Sites WC 1, WC 2, and WC 3. (Site WC 3 was used in measurements of terrain/vegetation Type G.)

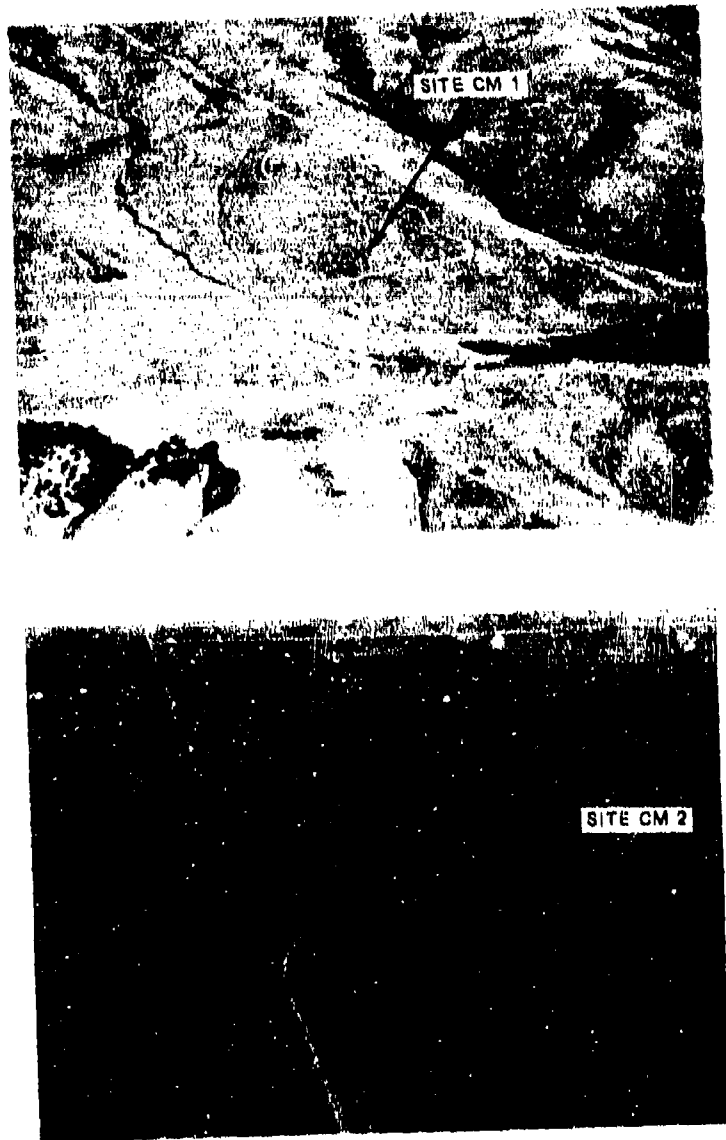


FIGURE 107. Aerial Photographs of Sites Used To Measure Terrain/Vegetation Type D, Showing Sites CM 1 and CM 2.

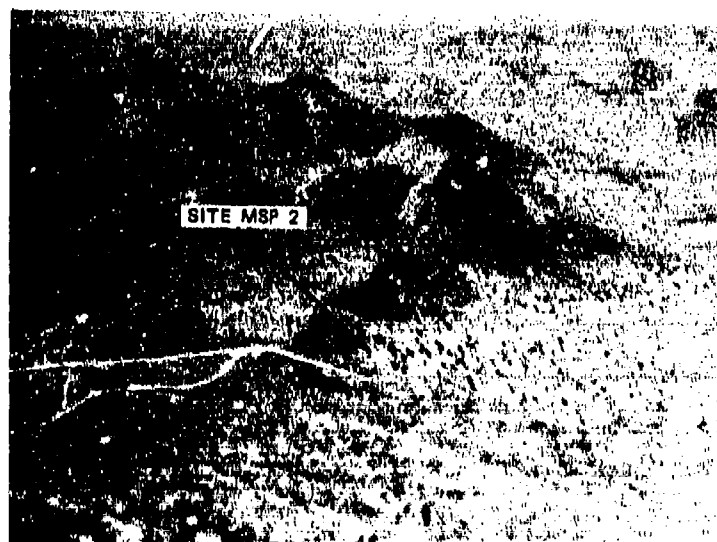


FIGURE 108. Aerial Photograph of Sites Used To Measure Terrain/Vegetation Type D, Showing Site MSP 2.



FIGURE 109. Site MSP 2, Ground Photograph.

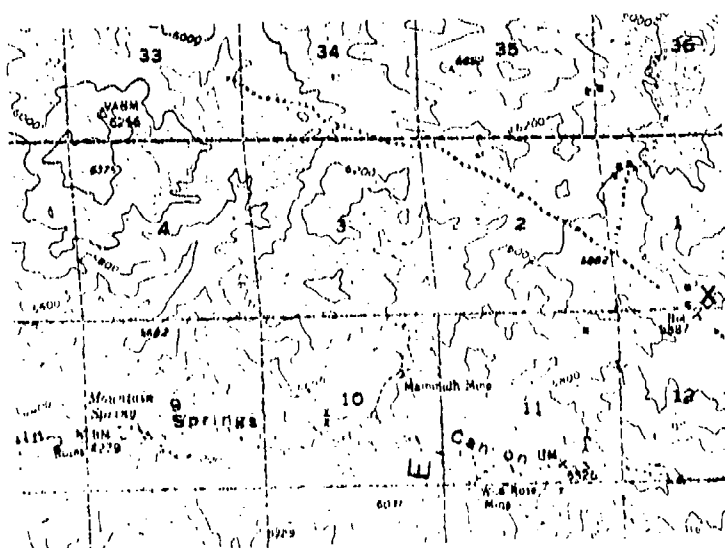


FIGURE 110. Site MSP 2, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

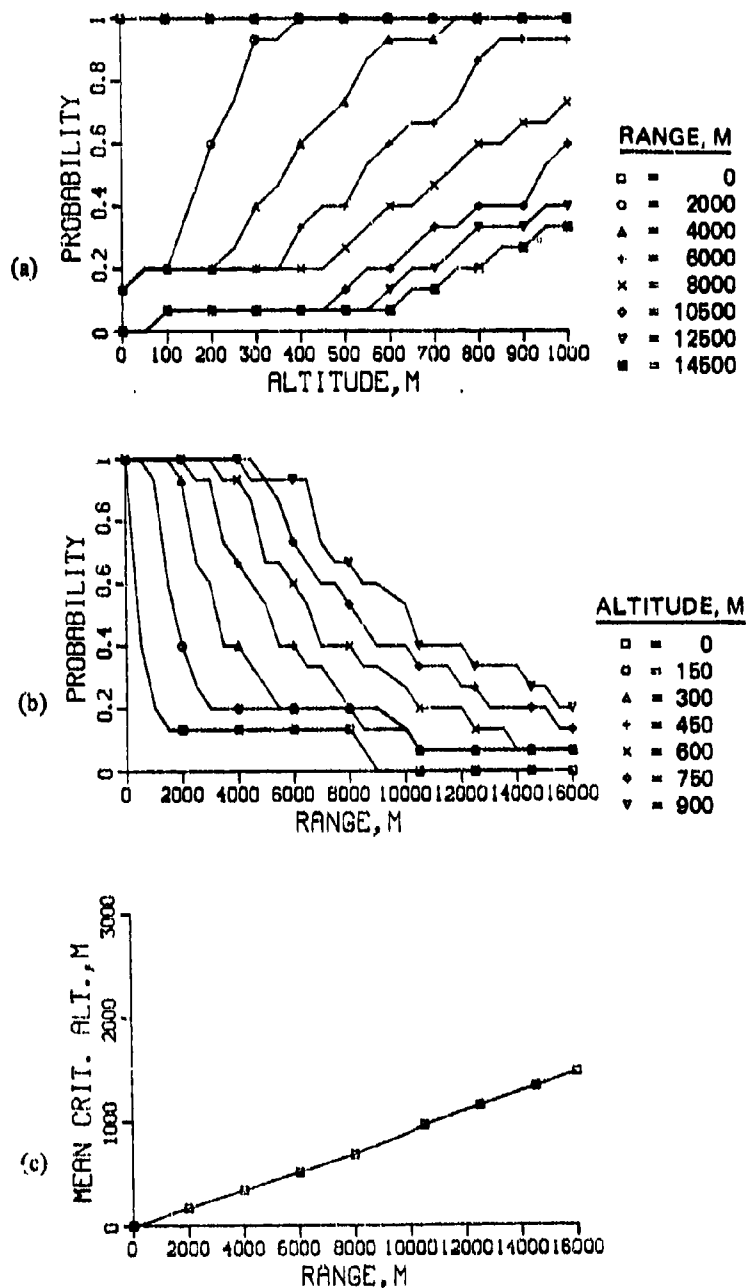


FIGURE 111. Site MSP 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, to and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

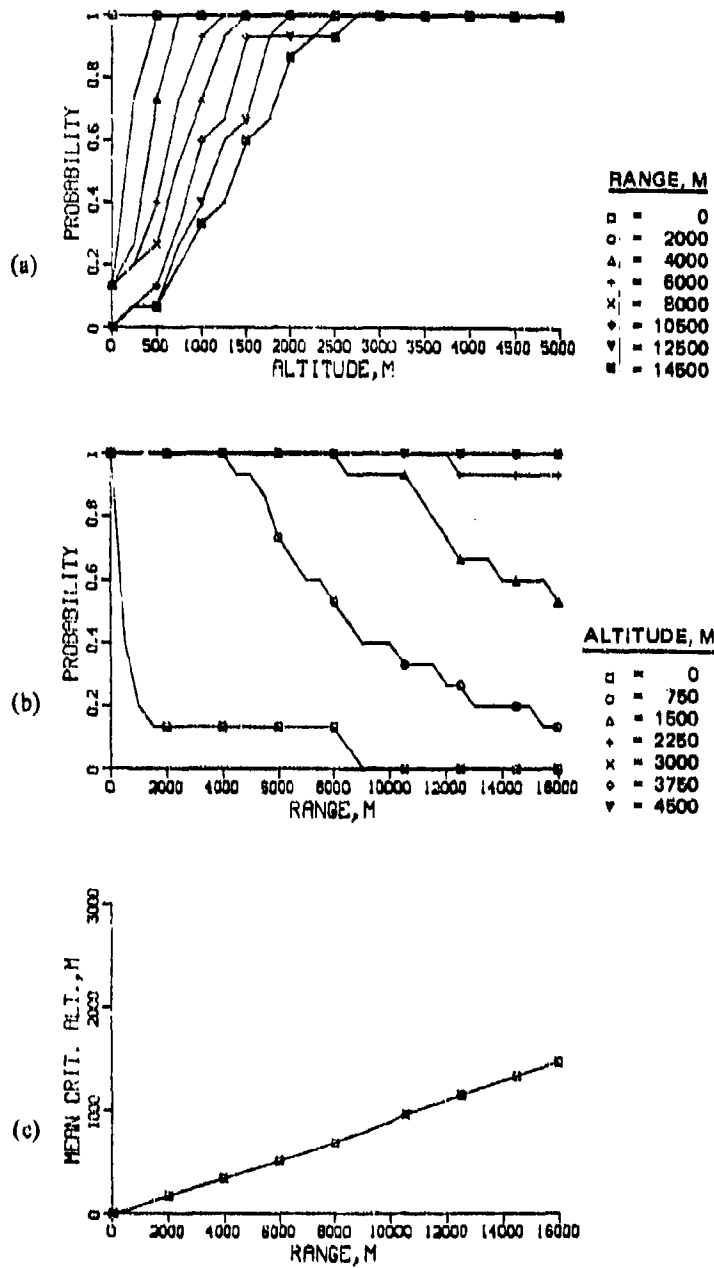


FIGURE 112. Site MSP 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 113. Site RDM 1, Ground Photograph.

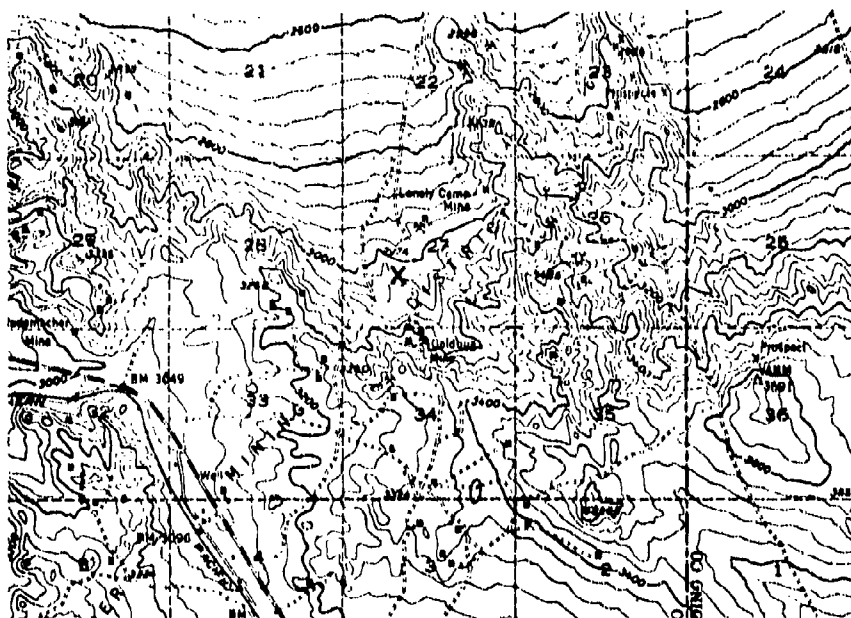


FIGURE 114. Site RDM 1, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

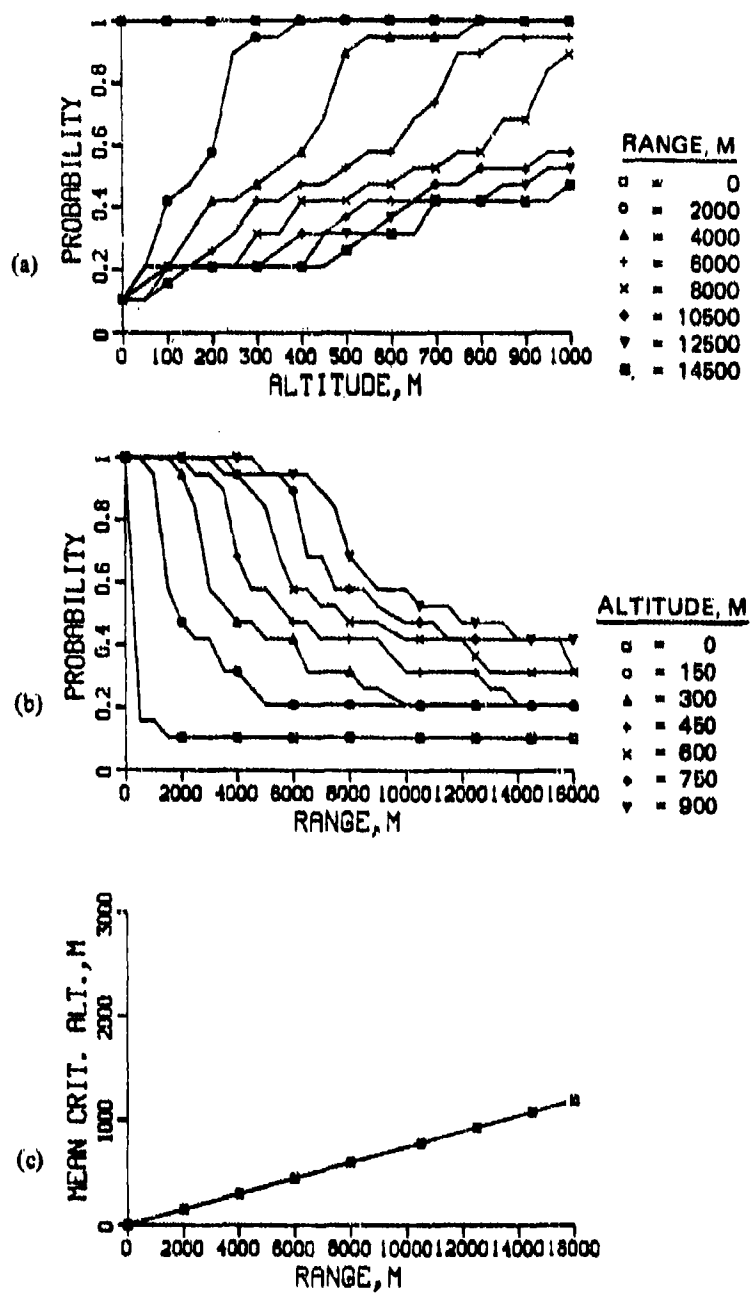


FIGURE 115. Site RDM 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

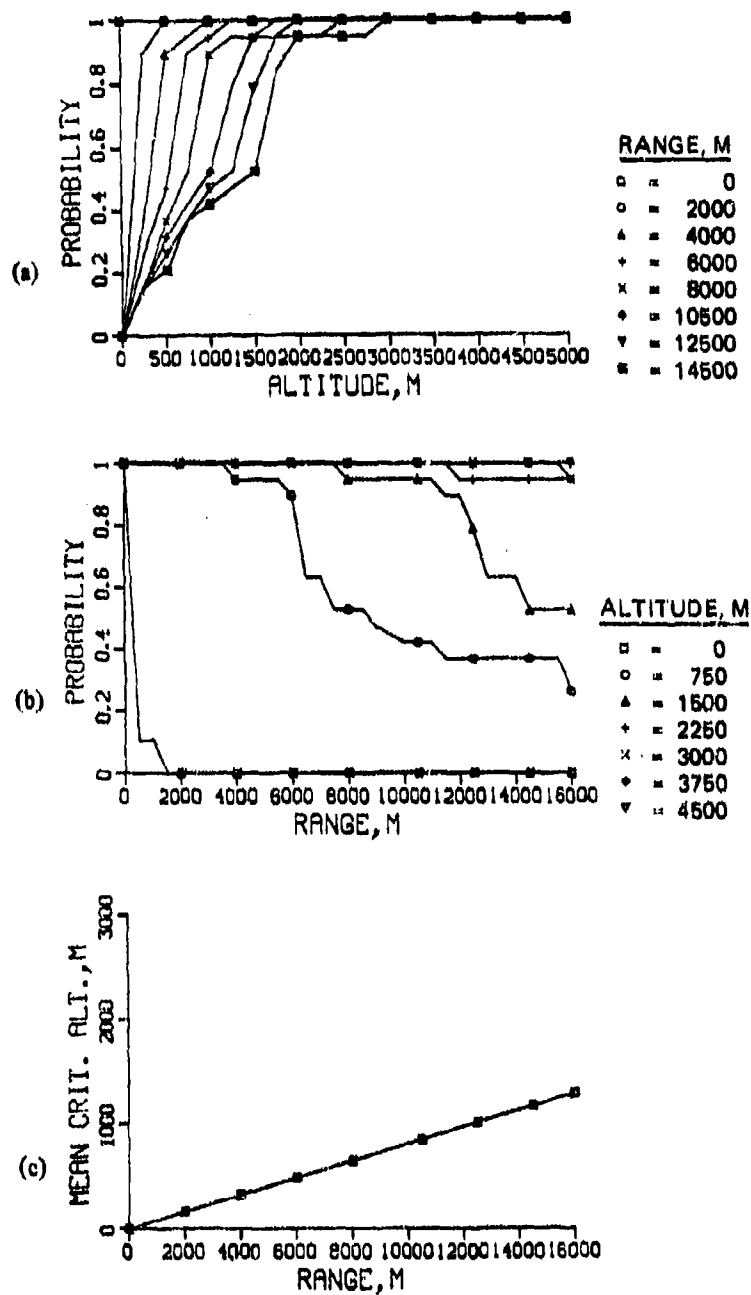


FIGURE 116. Site RDM 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 117. Site WC 1, Ground Photograph.

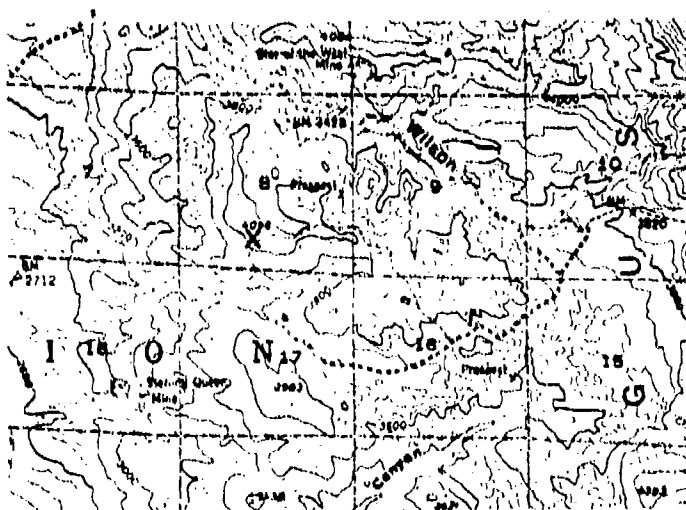


FIGURE 118. Site WC 1, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

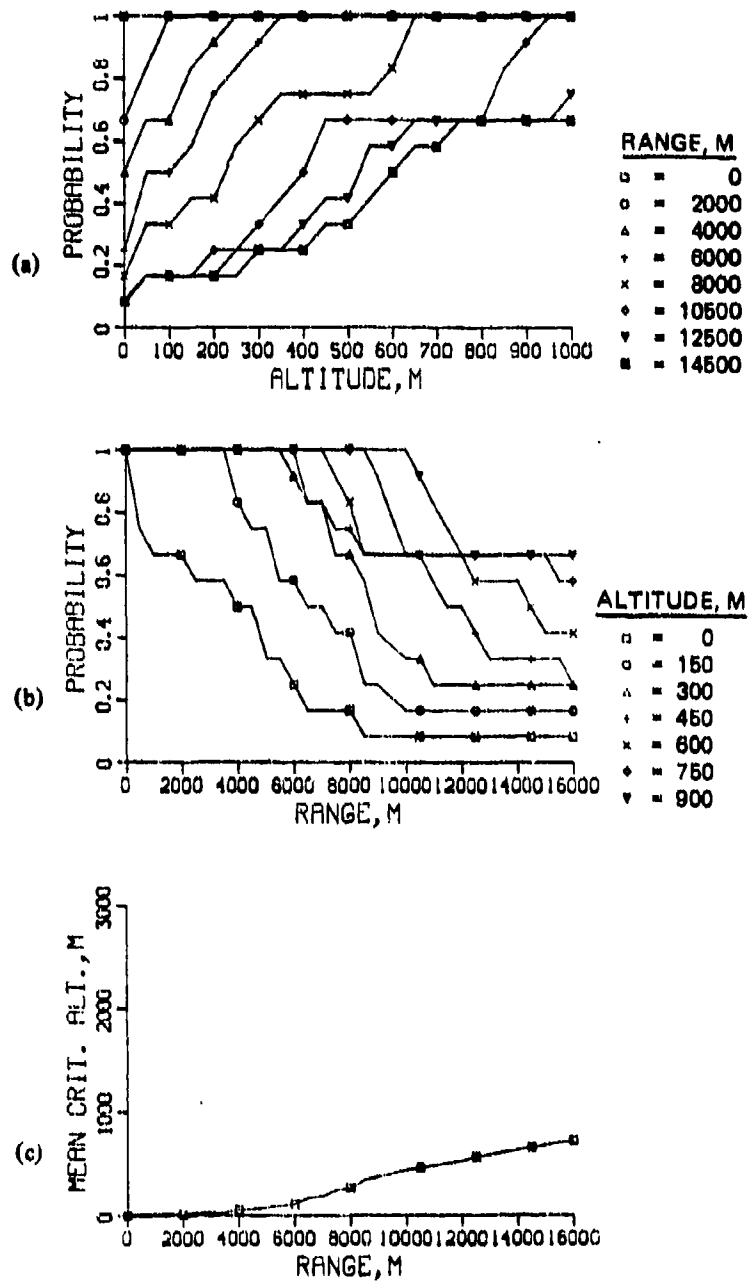


FIGURE 119. Site WC 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

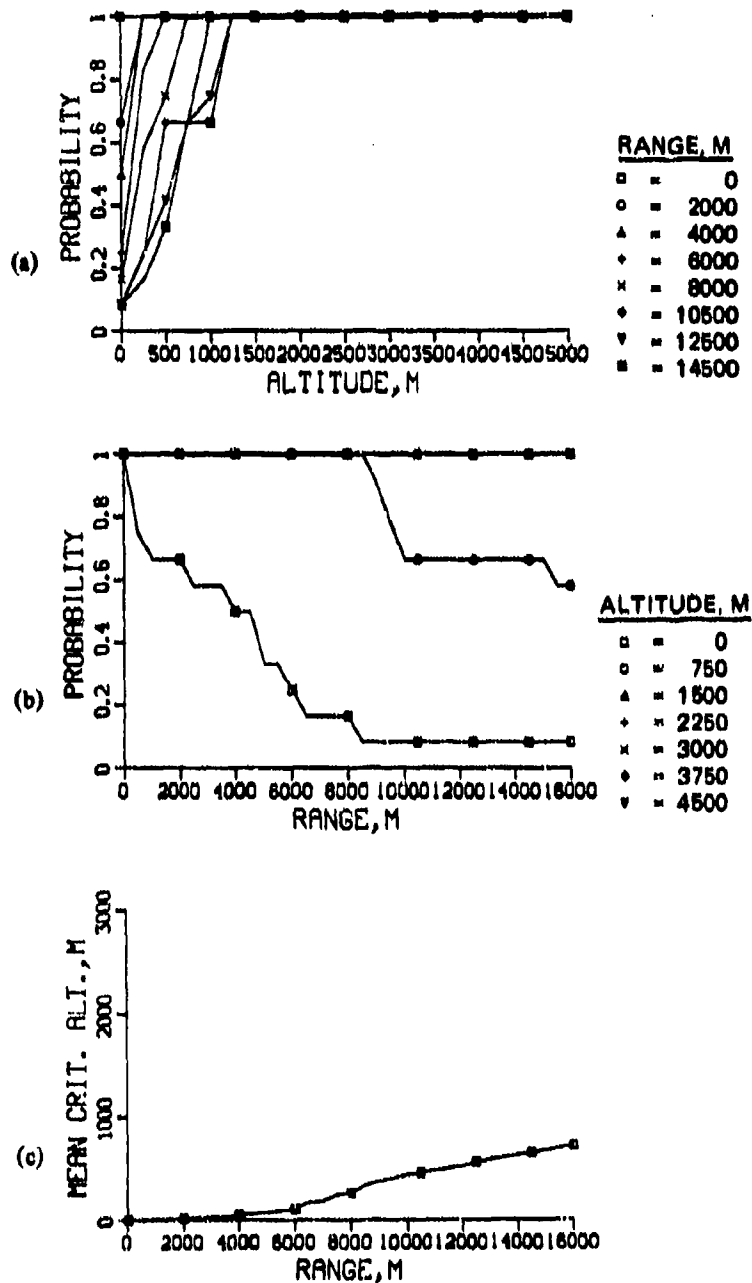


FIGURE 120. Site WC 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 121. Site WC 2, Ground Photograph.

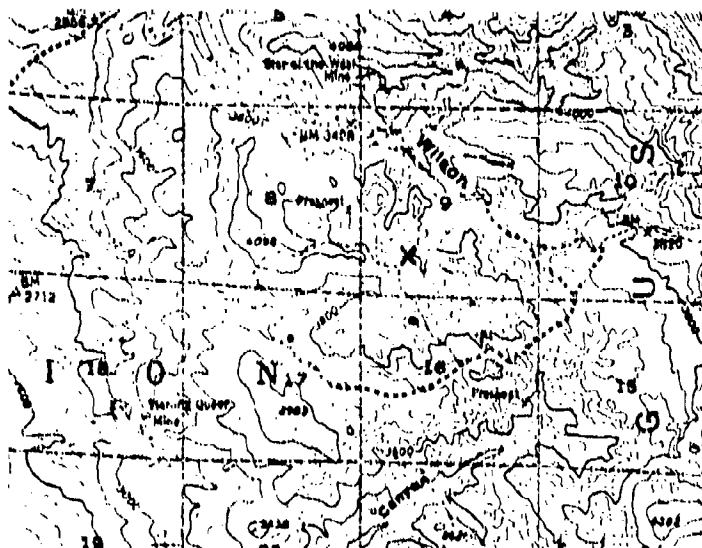


FIGURE 122. Site WC 2, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

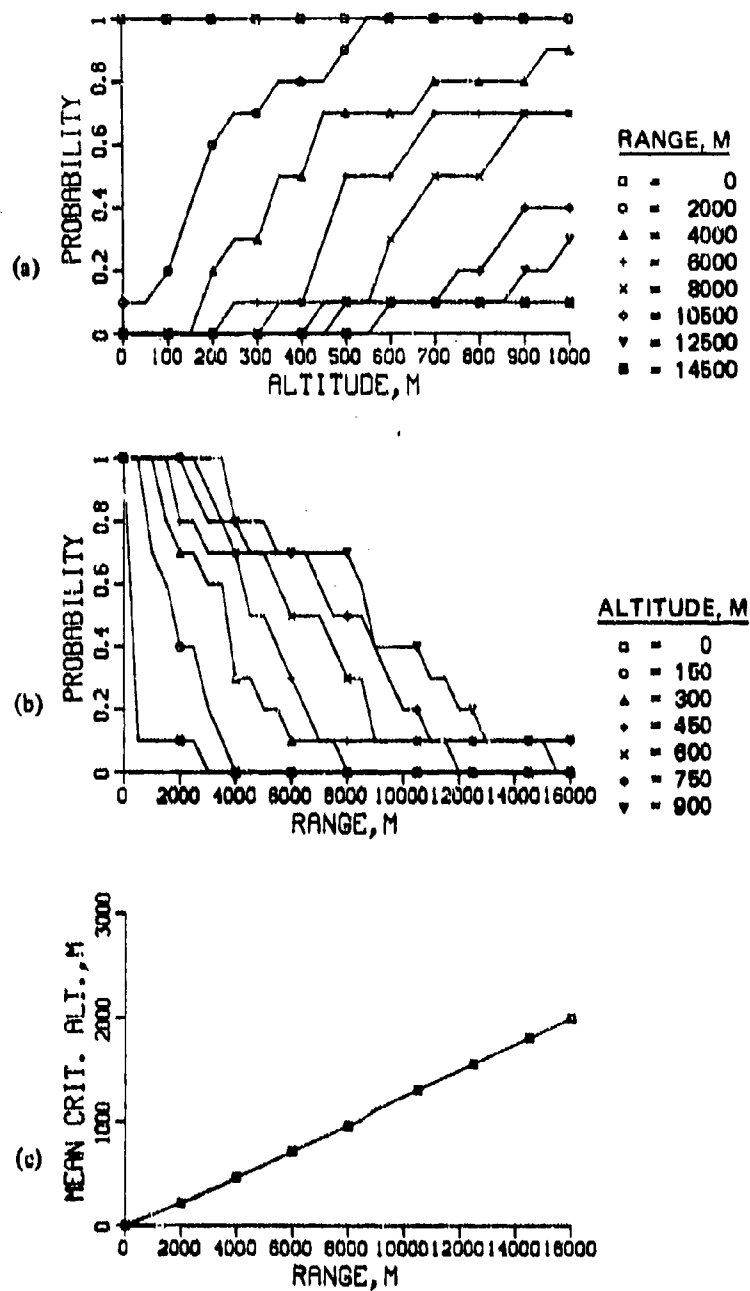


FIGURE 123. Site WC 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

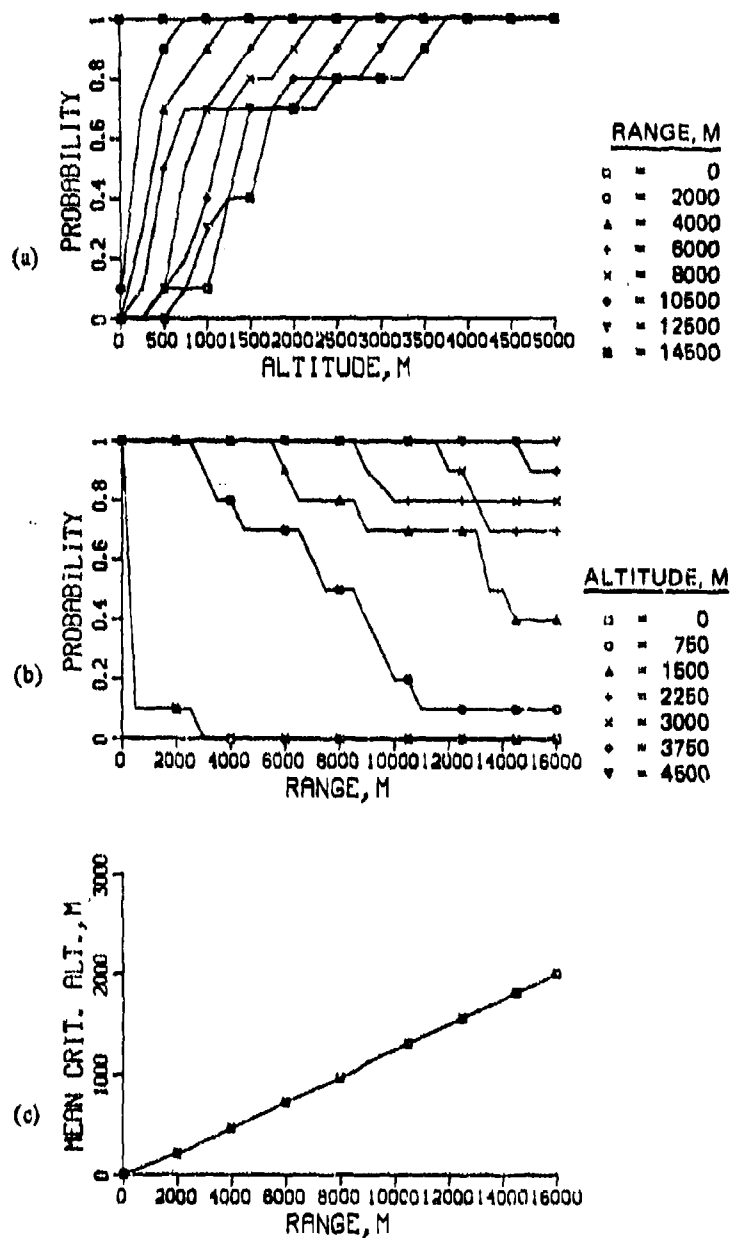


FIGURE 124. Site WC 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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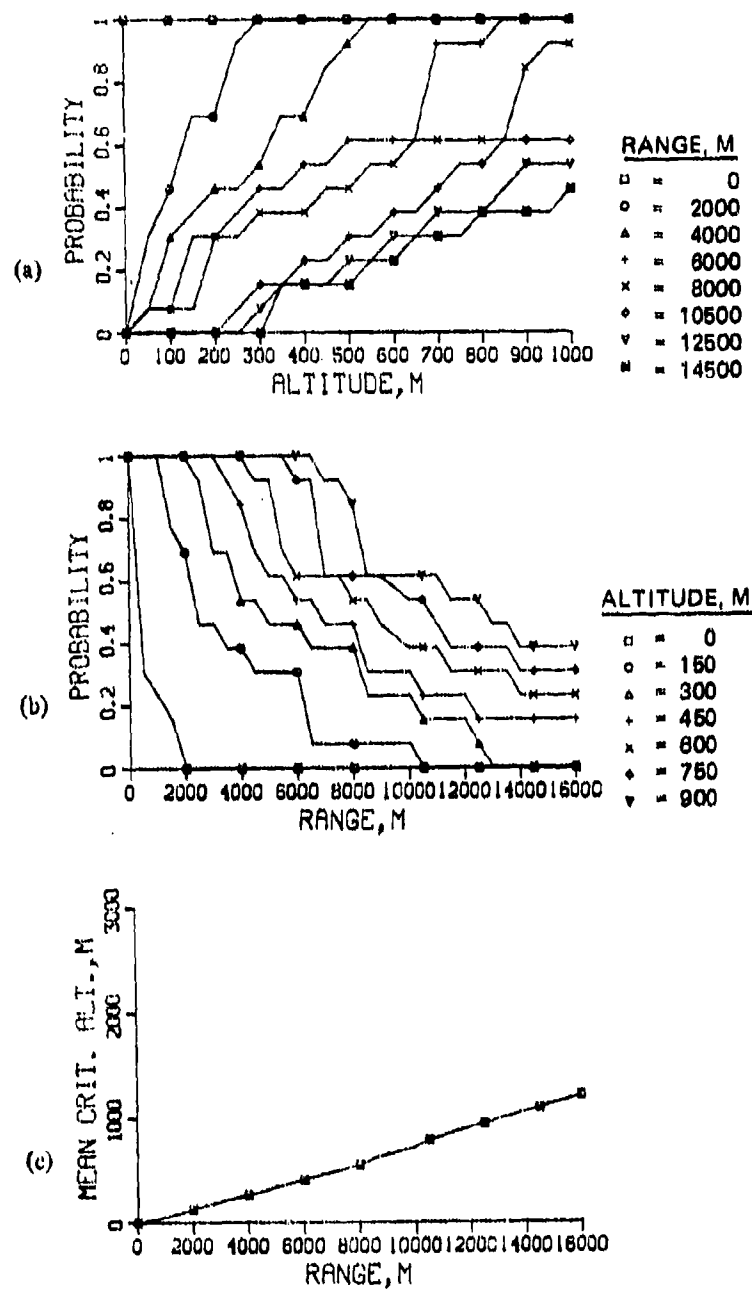


FIGURE 127. Site CM 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

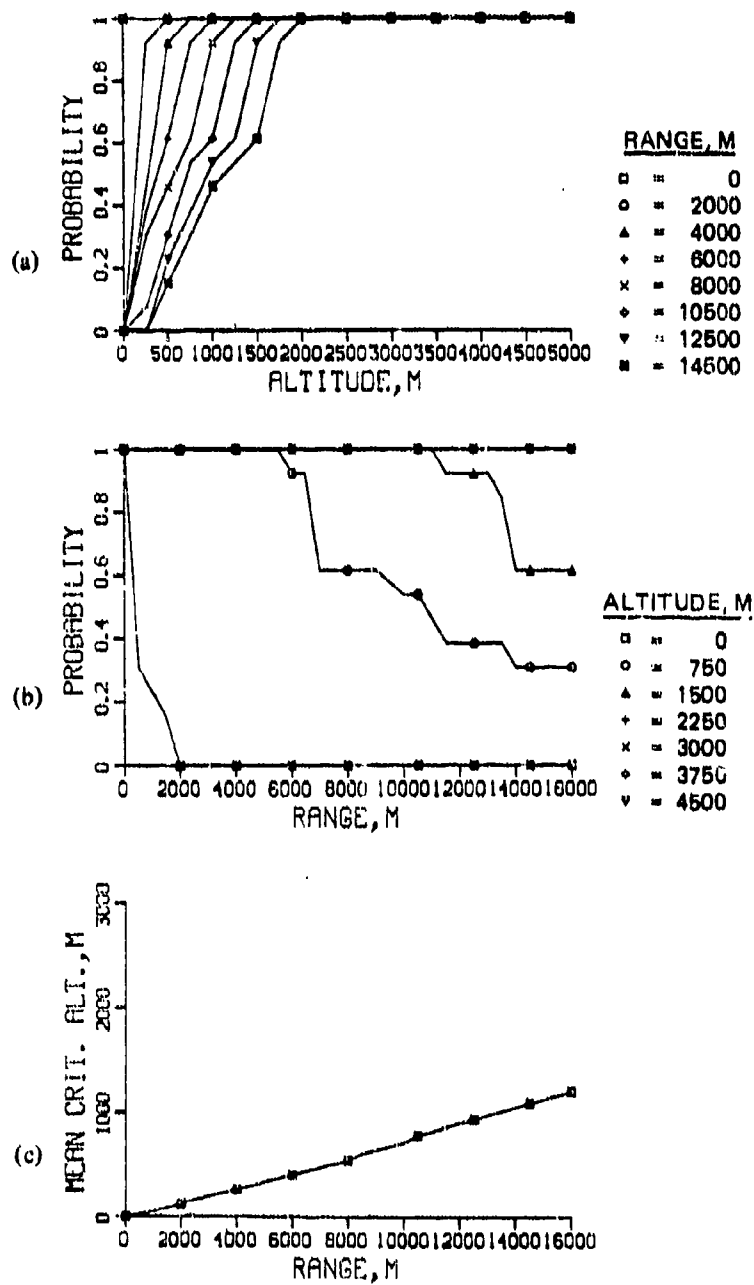


FIGURE 128. Site CM 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

121

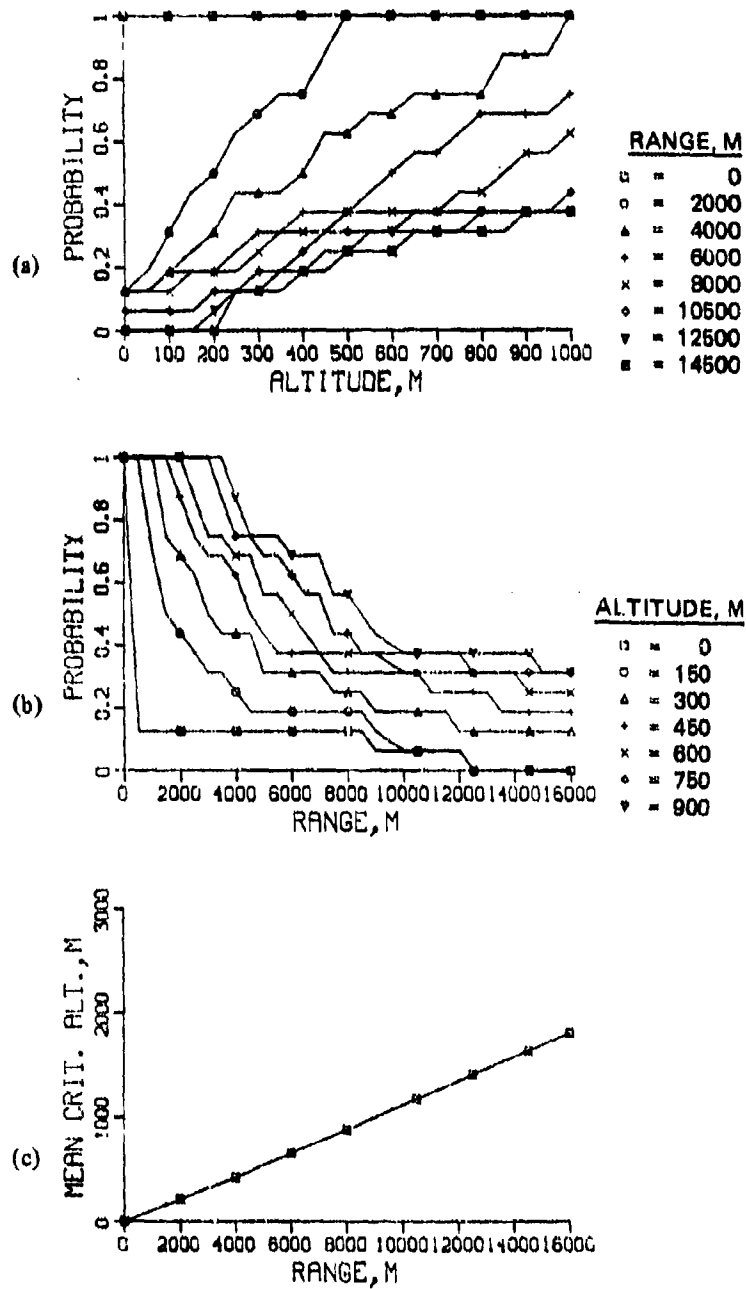


FIGURE 131. Site CM 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

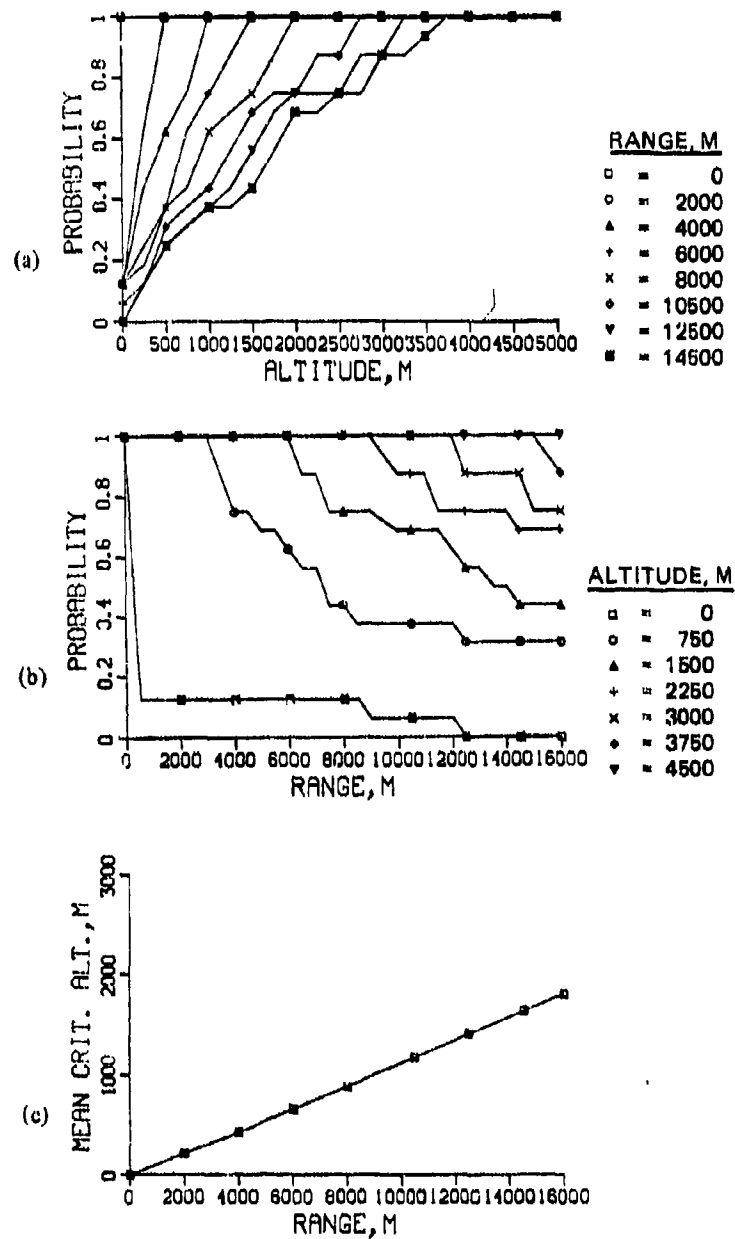


FIGURE 132. Site CM 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

TERRAIN/VEGETATION TYPE E

Description: Farmland, flat, with thick forests close in.

Data available: Ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs (see Figures 133 through 152).

Number of sites surveyed: Five.

Site designations: CHE 2, CHE 3, CHE 4, HB 2, SLC.

Approximate number of LOS measurements: 100.



FIGURE 133. Site CHE 2, Ground Photograph.

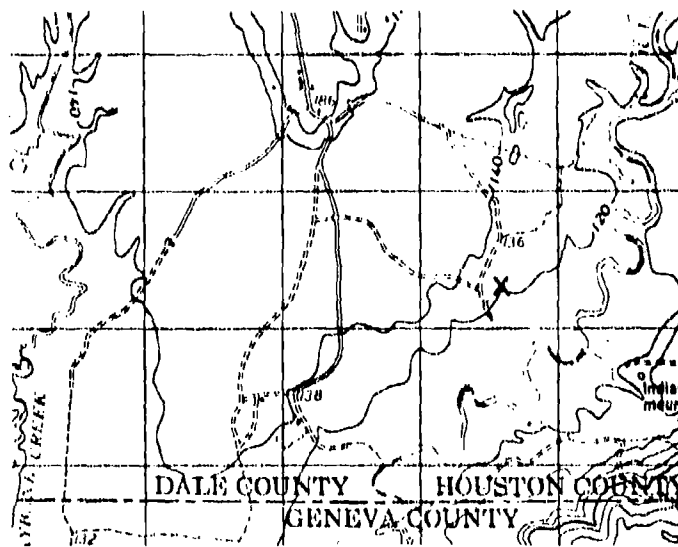


FIGURE 134. Site CHE 2, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

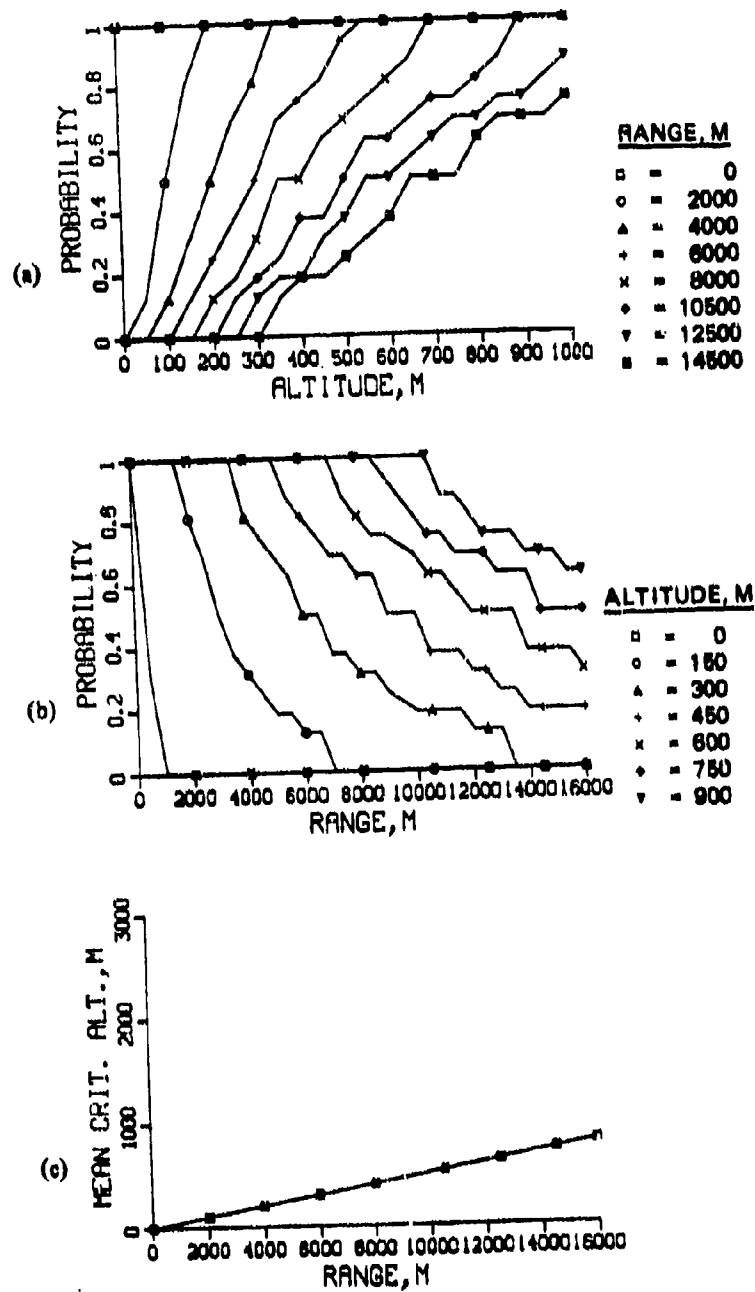


FIGURE 135. Site CHE 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

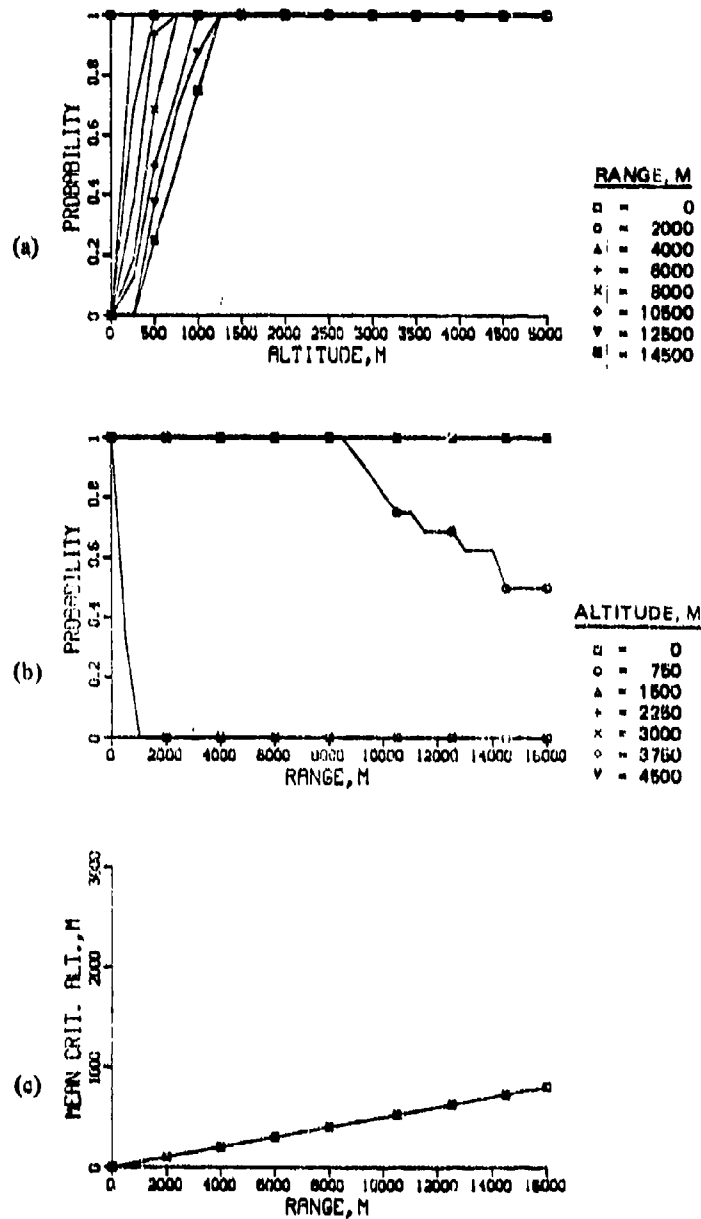


FIGURE 136. Site CHE 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 137. Site CHE 3, Ground Photograph.

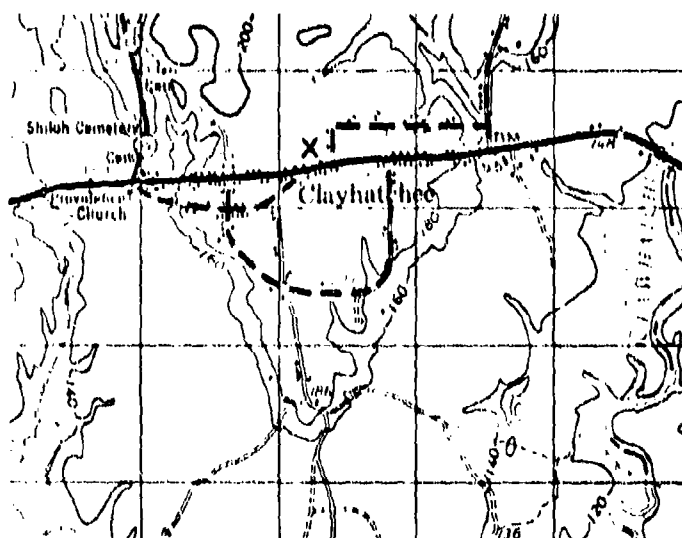


FIGURE 138. Site CHE 3, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

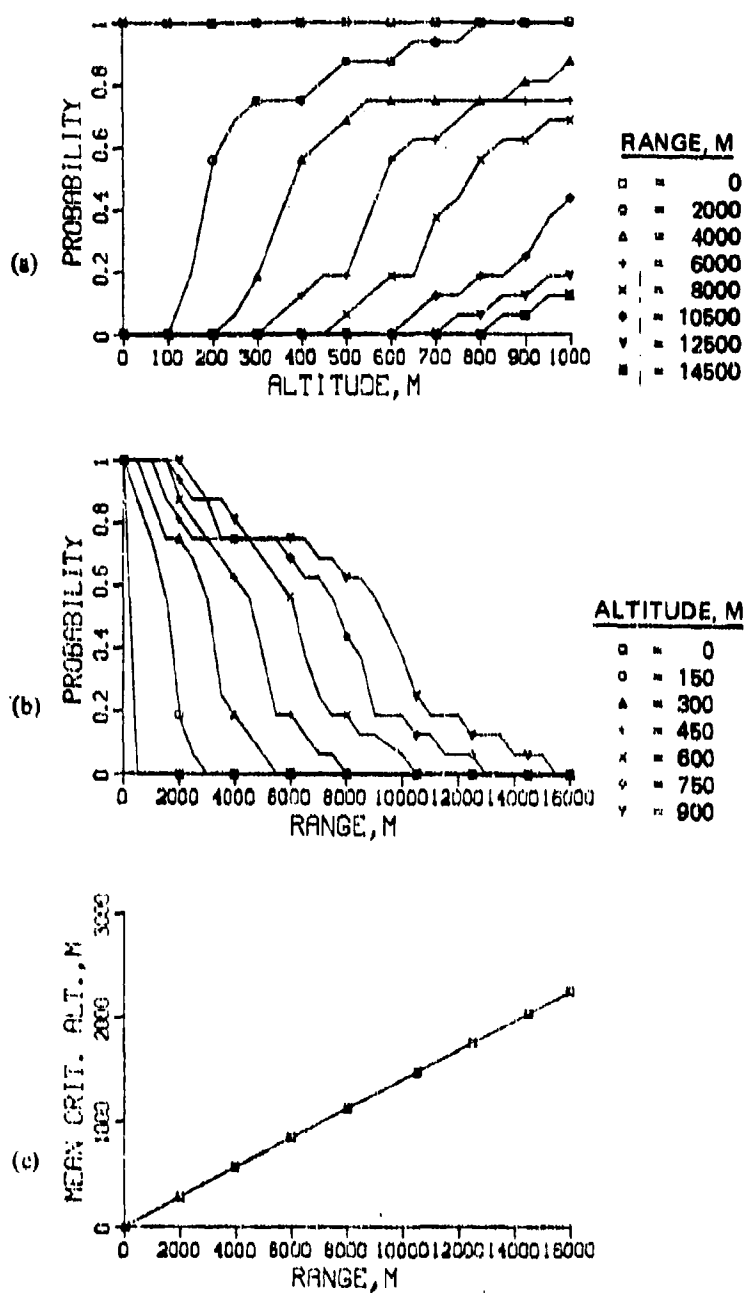


FIGURE 139. Site CHE 3: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

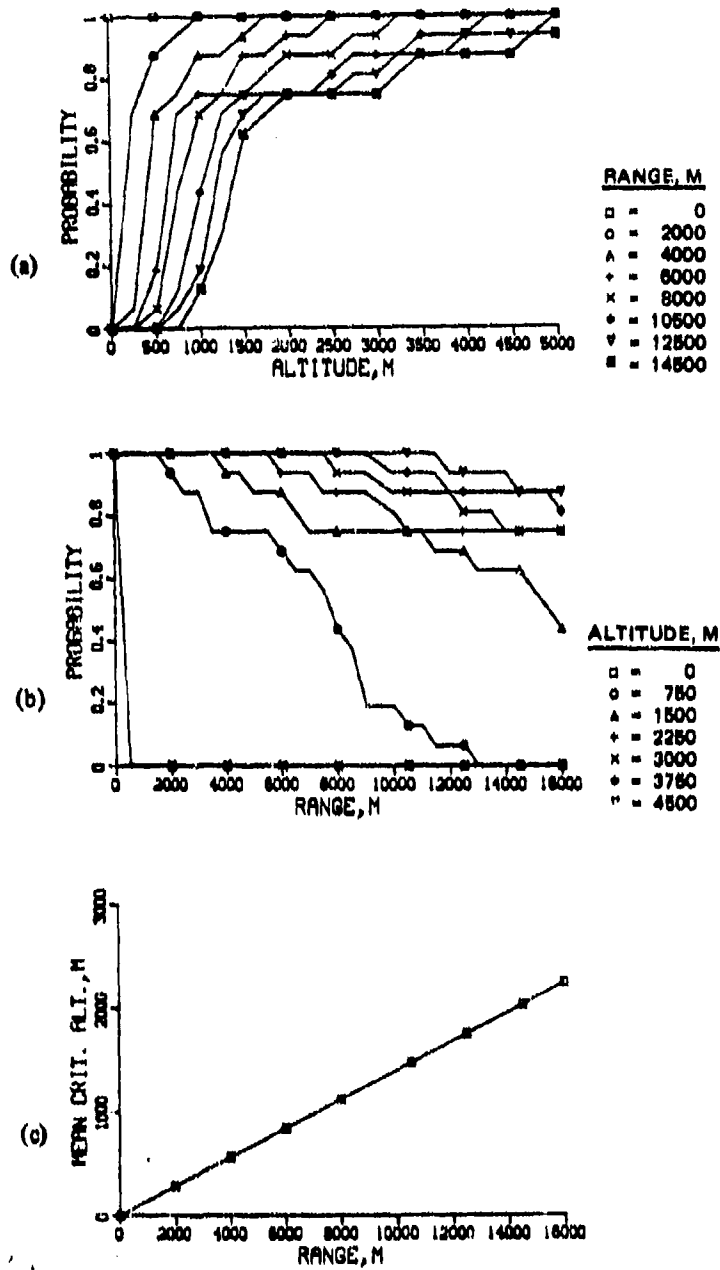


FIGURE 140. Site CHE 3: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 141. Site CHE 4, Ground Photograph.

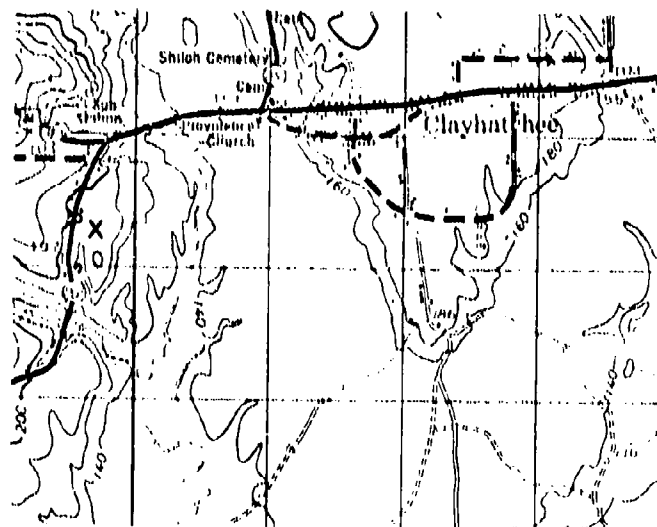


FIGURE 142. Site CHE 4, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

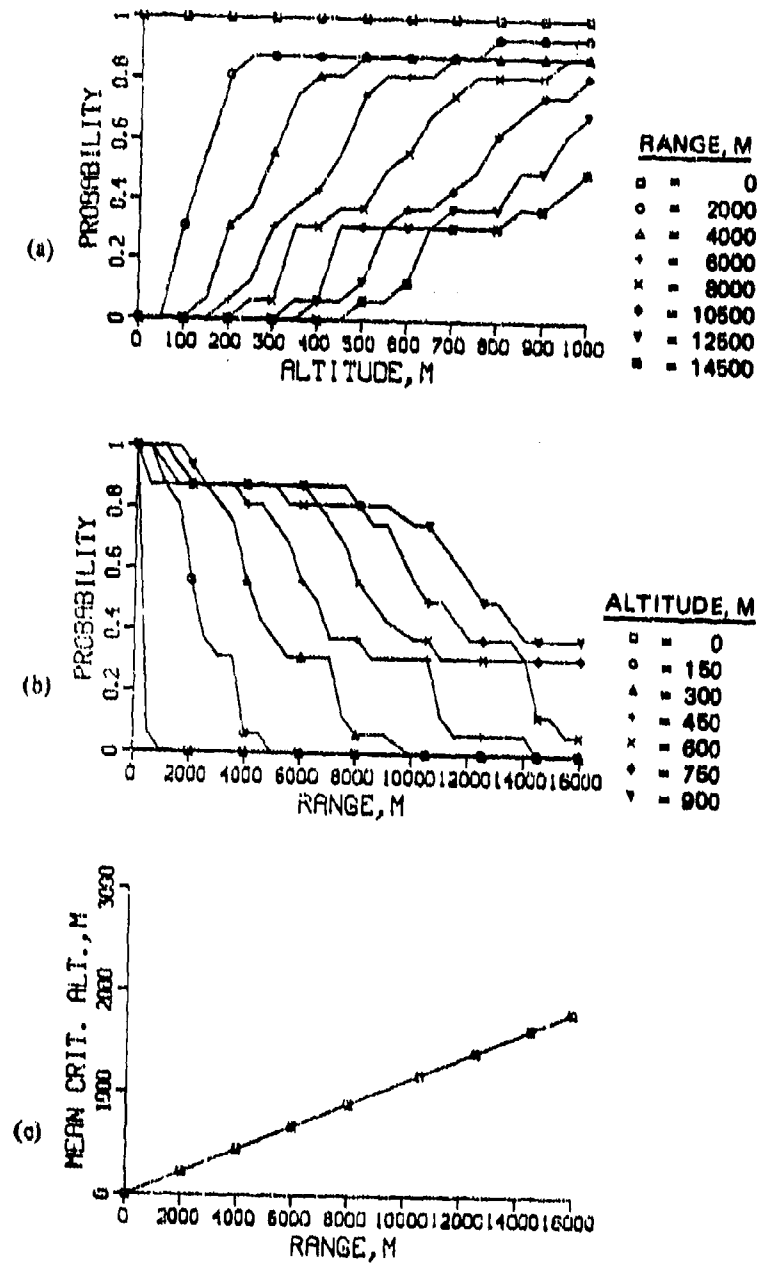


FIGURE 143. Site CHE 4: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

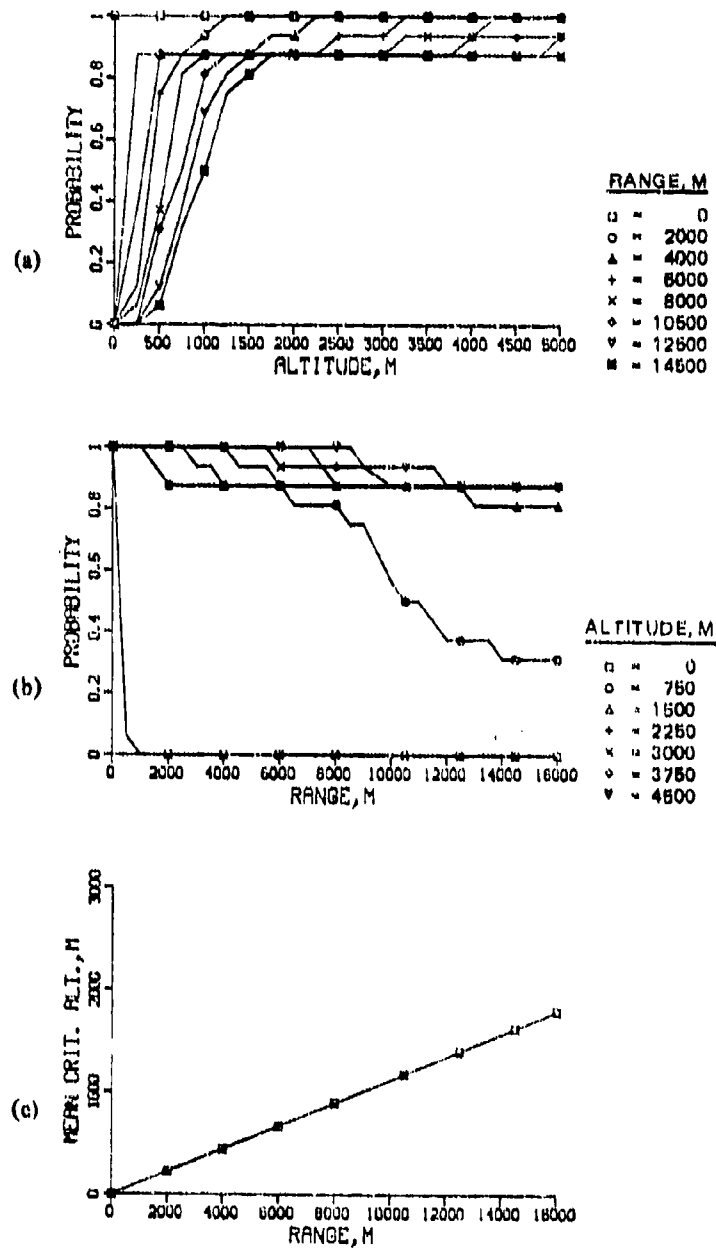


FIGURE 144. Site CHE 4: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.



FIGURE 145. Site HB 2, Ground Photograph.

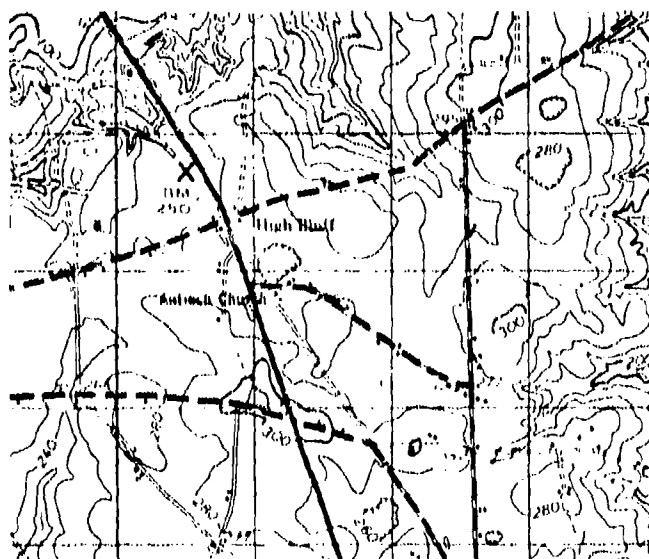


FIGURE 146. Site HB 2, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

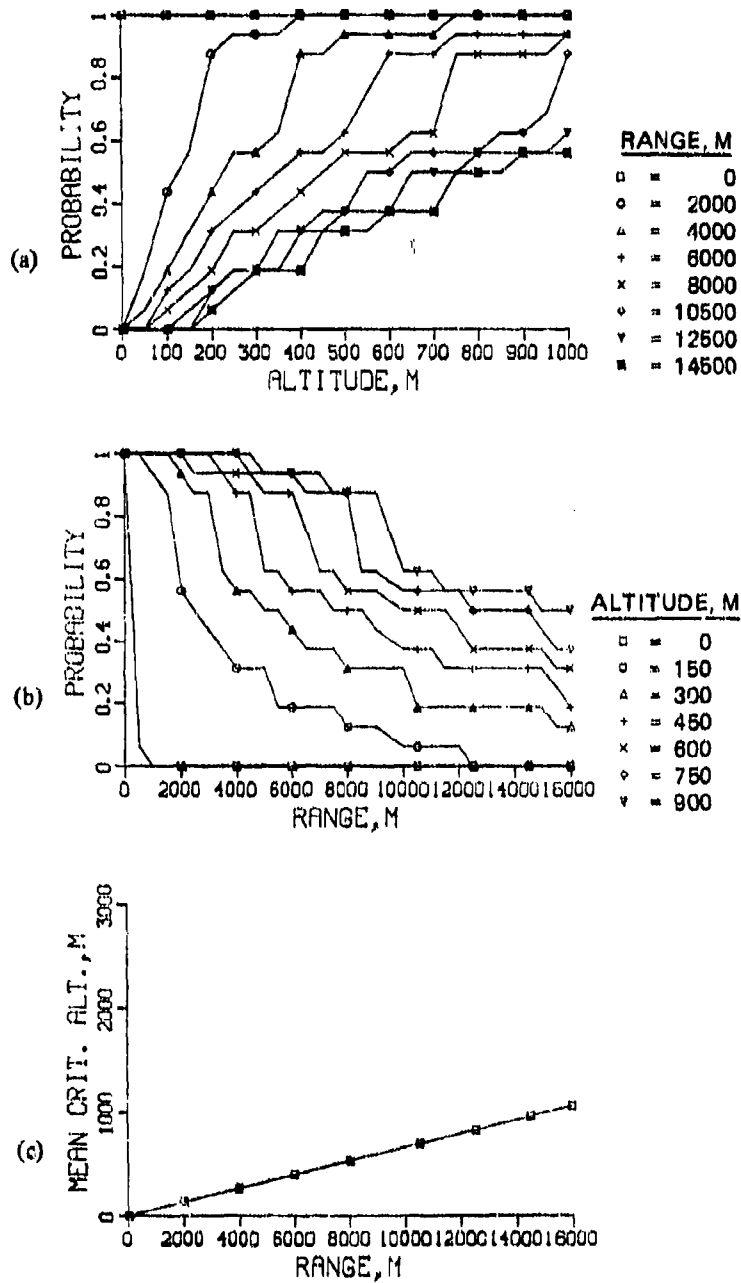


FIGURE 147. Site HB 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

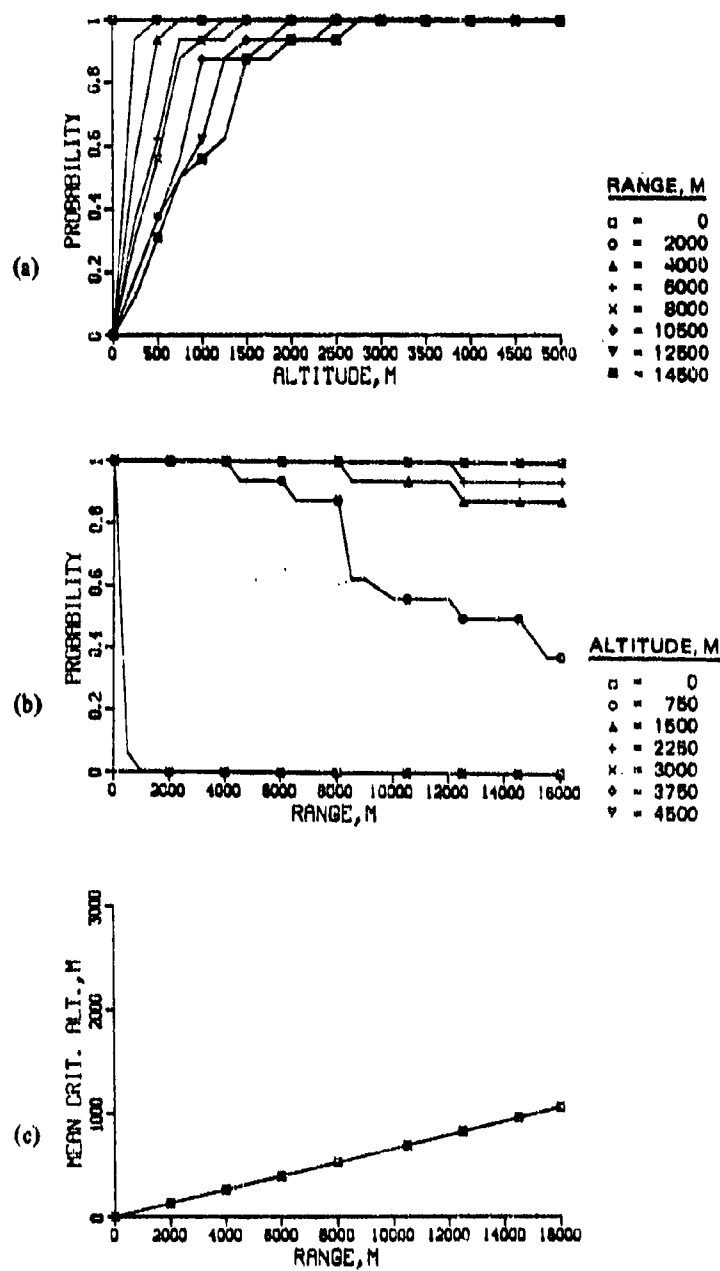


FIGURE 148. Site HB 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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FIGURE 149. Site SLC, Ground Photograph.

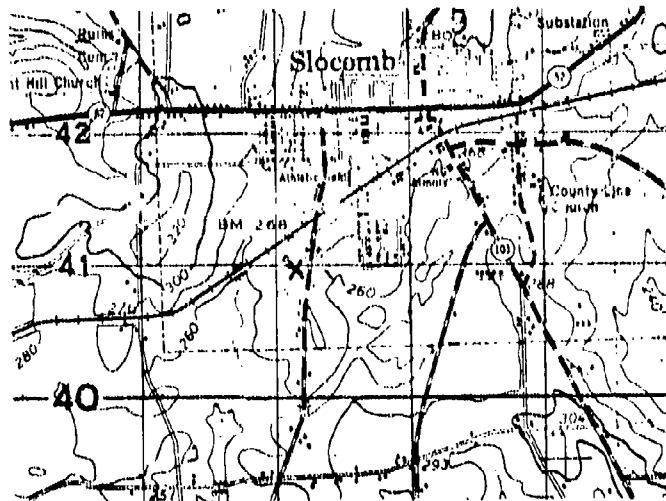


FIGURE 150. Site SLC, Topographic Map. Scale is 1:50,000; contour interval is 20 ft.

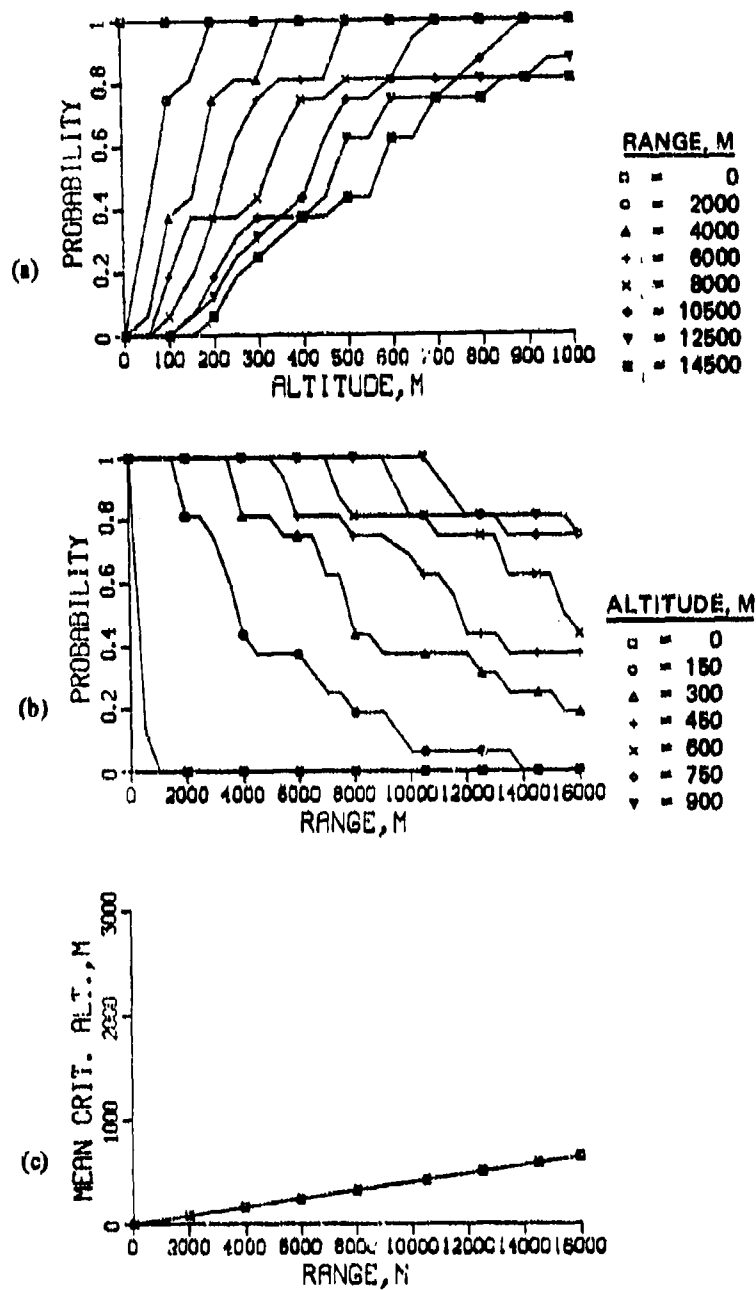


FIGURE 151. Site SLC: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

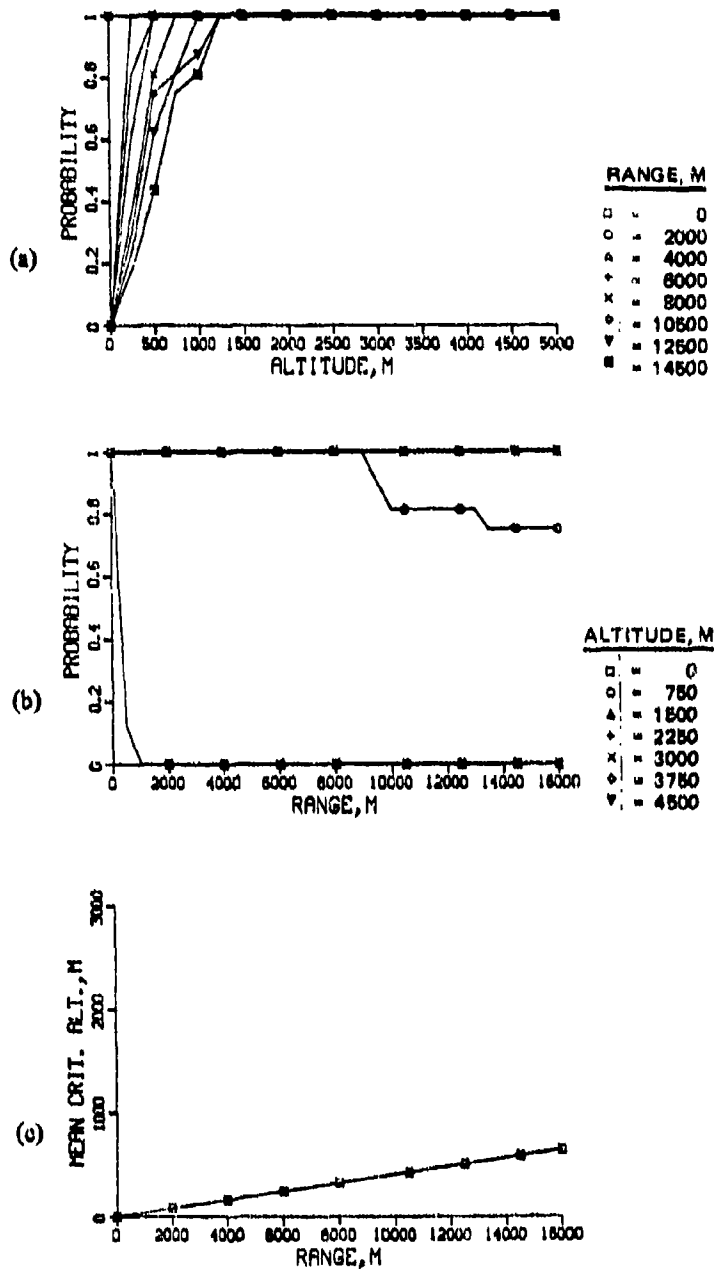


FIGURE 152. Site SLC: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

TERRAIN/VEGETATION TYPE F

Description: Hills, gently rolling, with scattered trees.

Data available: Aerial photographs, ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs (see Figures 153 through 170).

Number of sites surveyed: Four.

Site designations: GH 1, GH 2, SSP 3, SSP 4.

Approximate number of LOS measurements: 80.

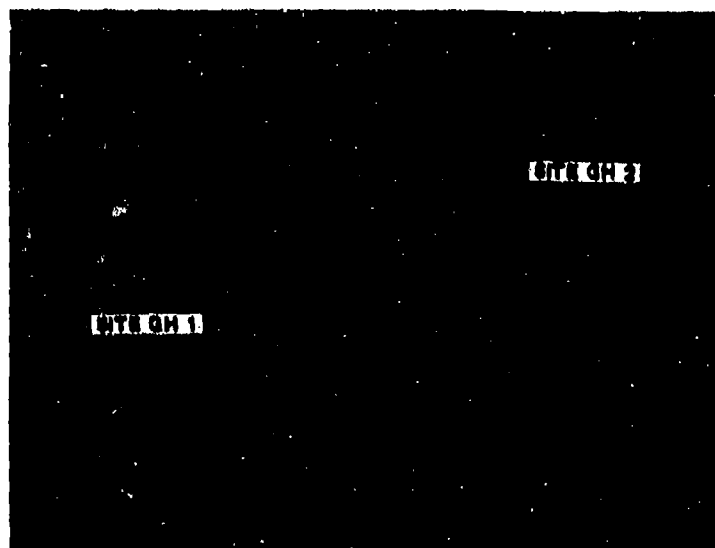


FIGURE 153. Aerial Photograph of Sites Used To Measure Terrain/Vegetation Type F, Showing Sites GH 1 and GH 2.



FIGURE 154. Aerial Photographs of Sites Used To Measure Terrain/Vegetation Type F, Showing Sites SSP 3 and SSP 4.

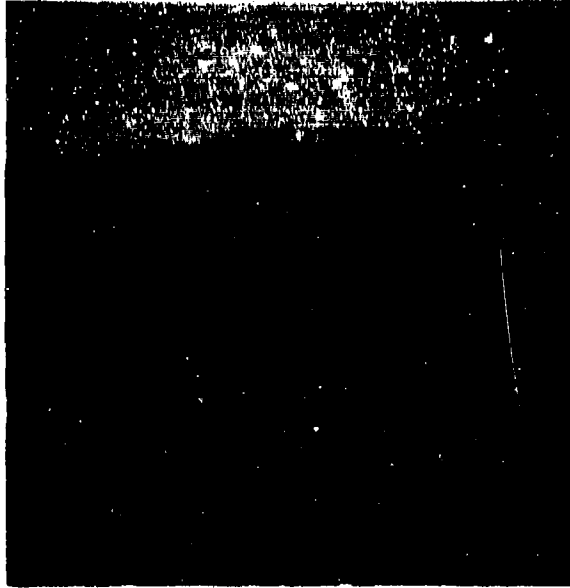


FIGURE 155. Site GH 1, Ground Photograph.

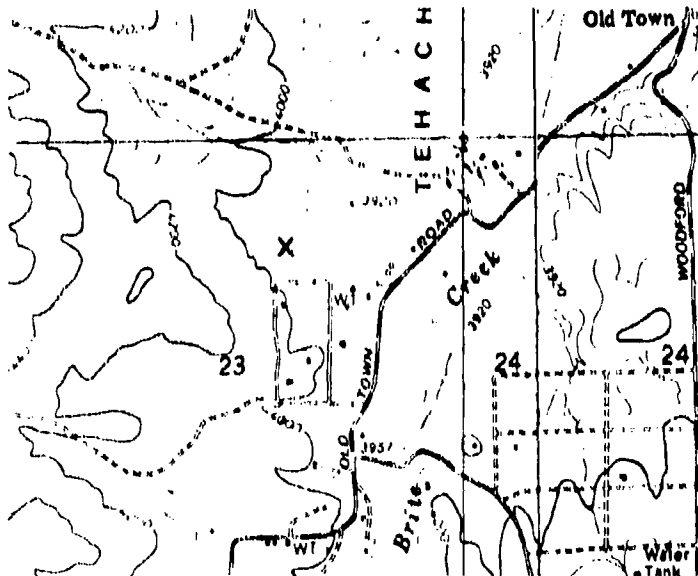


FIGURE 156. Site GH 1, Topographic Map. Scale is 1:24,000; contour interval is 40 ft.

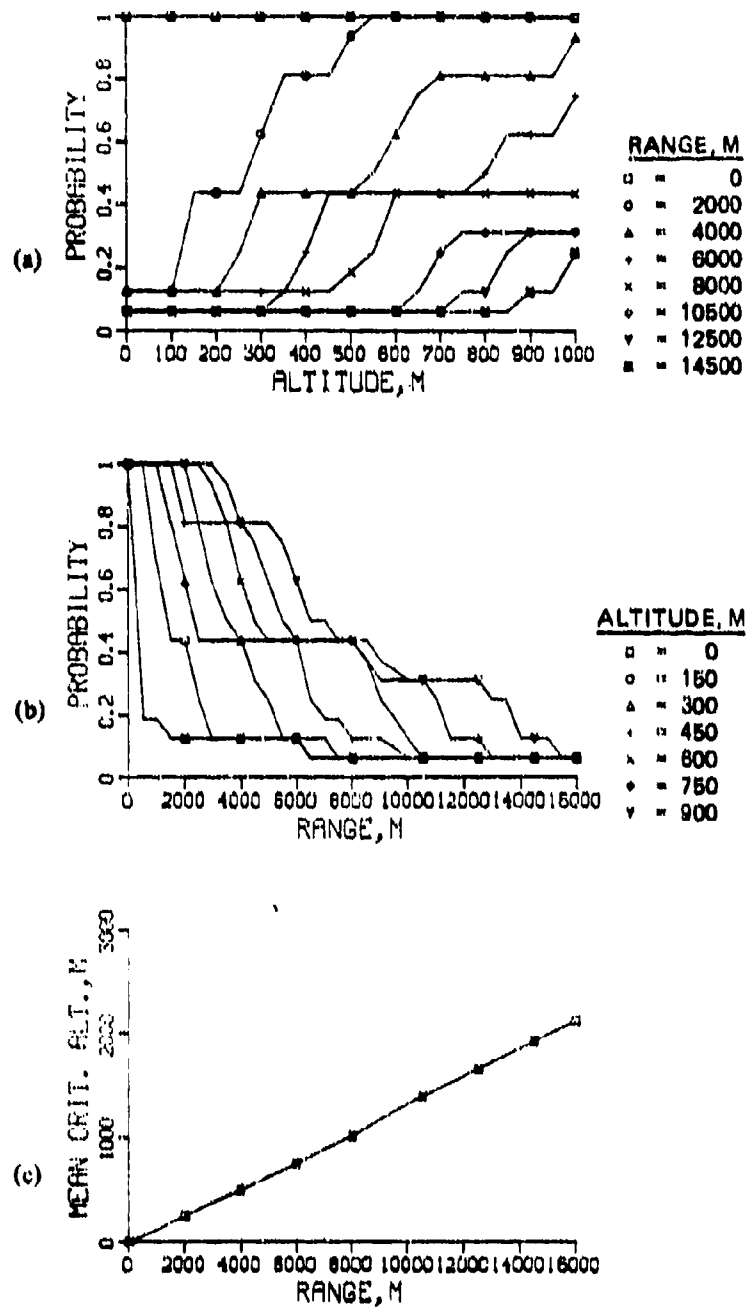


FIGURE 157. Site GH 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

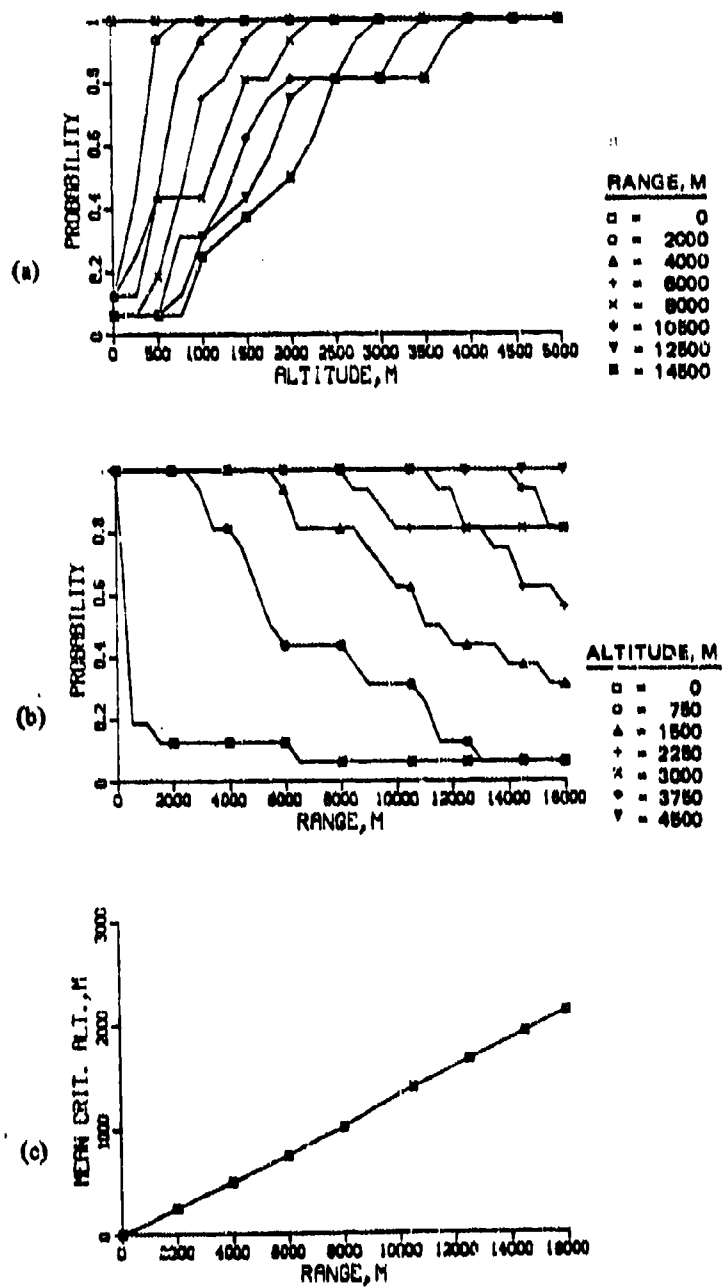


FIGURE 158. Site GH 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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FIGURE 159. Site GH 2, Ground Photograph.

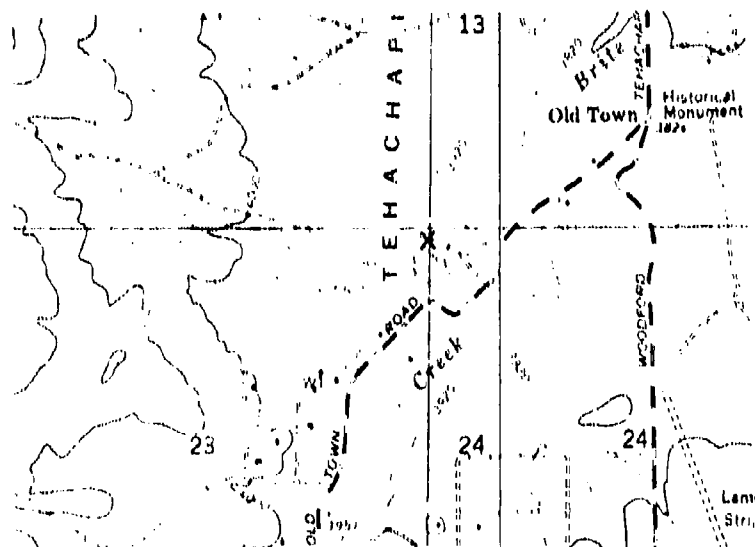


FIGURE 160. Site GH 2, Topographic Map. Scale is 1:24,000; contour interval is 40 ft.

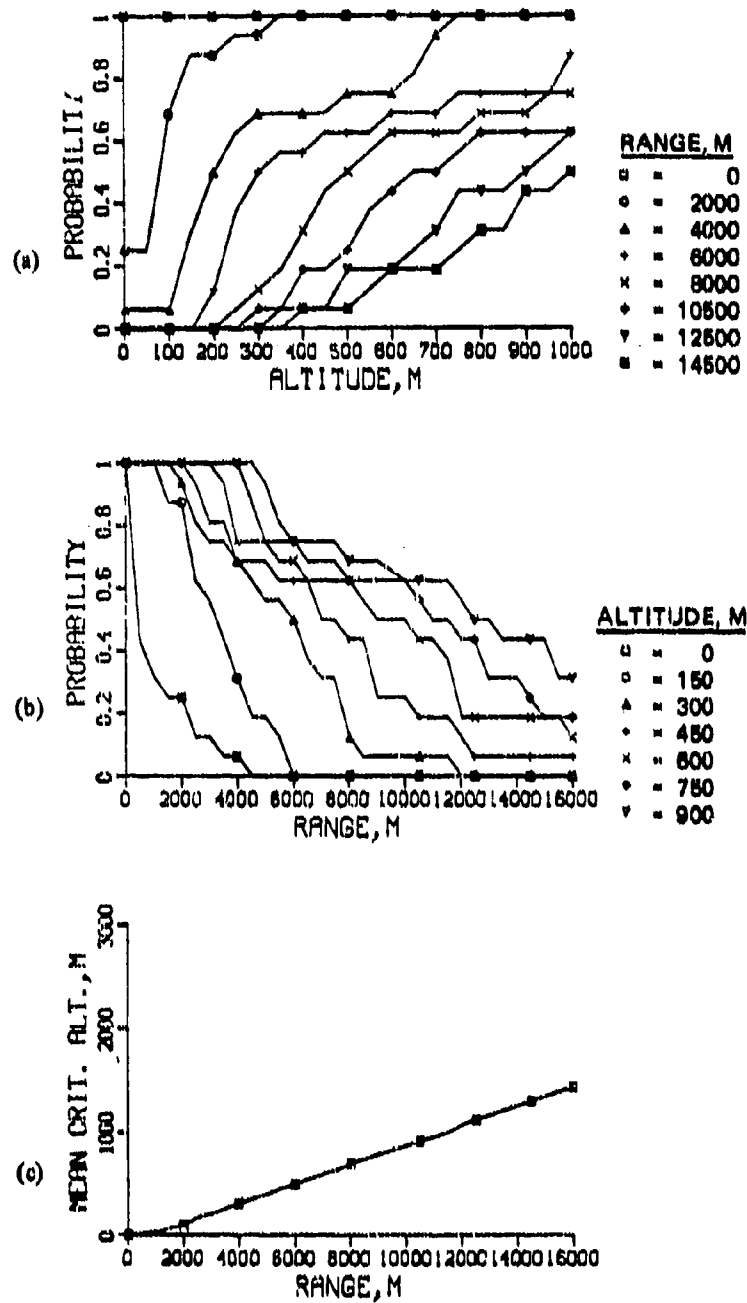


FIGURE 161. Site GH 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

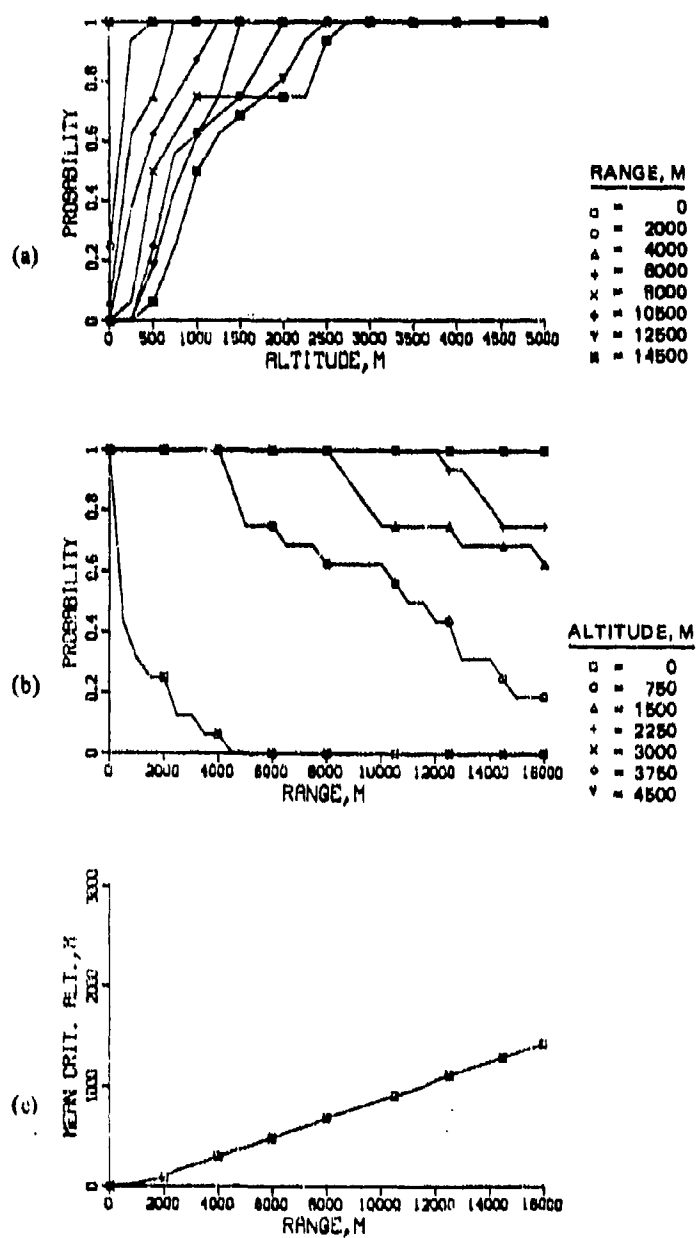


FIGURE 162. Site GH 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

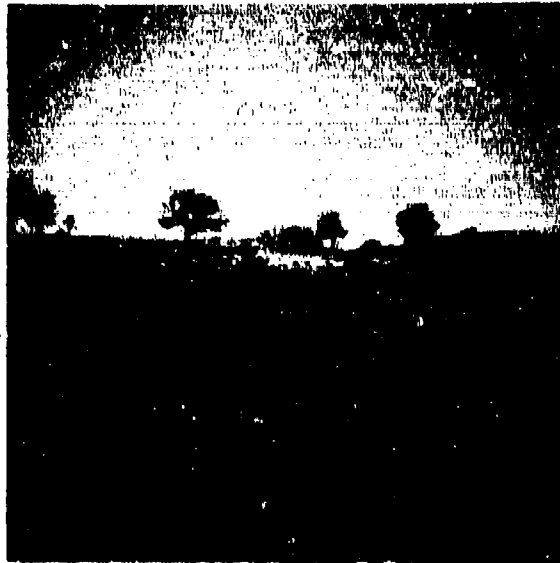


FIGURE 163. Site SSP 3, Ground Photograph.

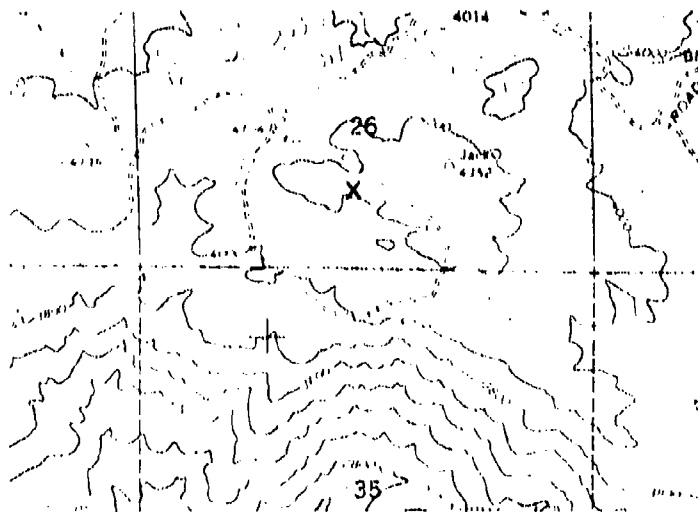


FIGURE 164. Site SSP 3, Topographic Map. Scale is 1:24,000; contour interval is 40 ft.

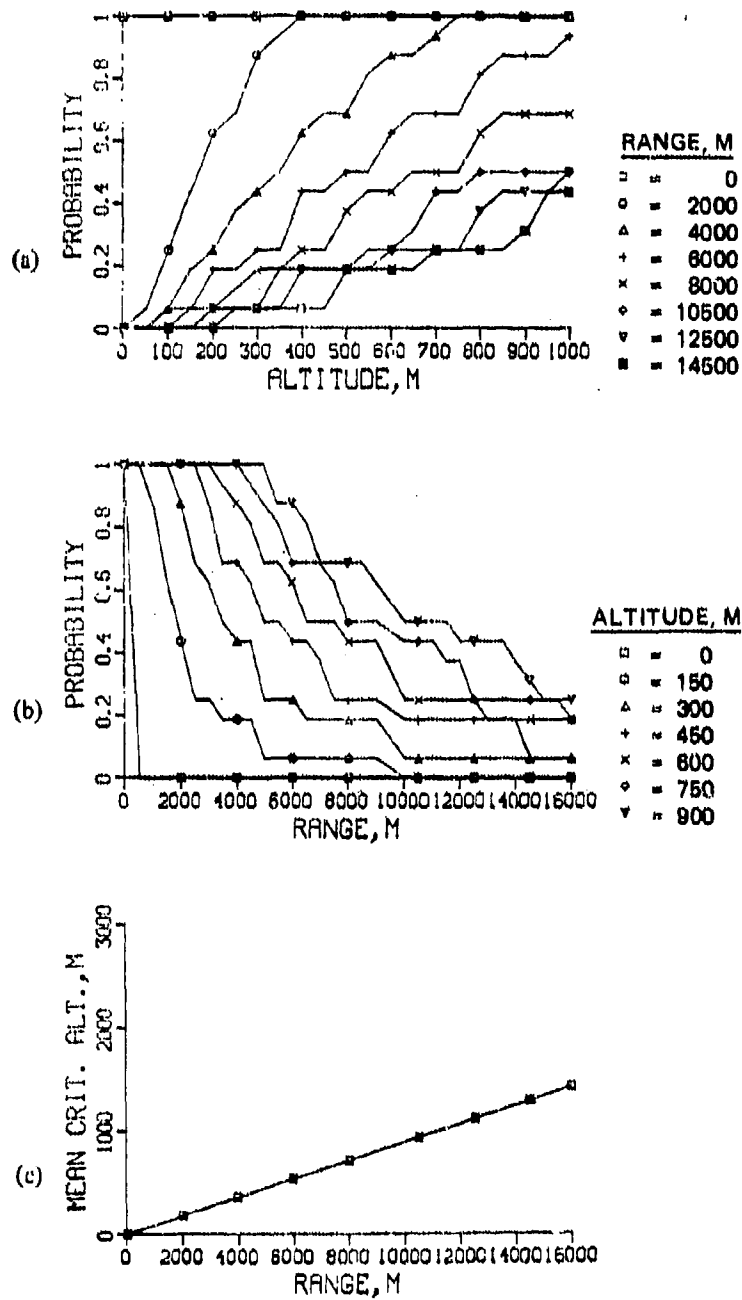


FIGURE 165. Site SSP 3: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

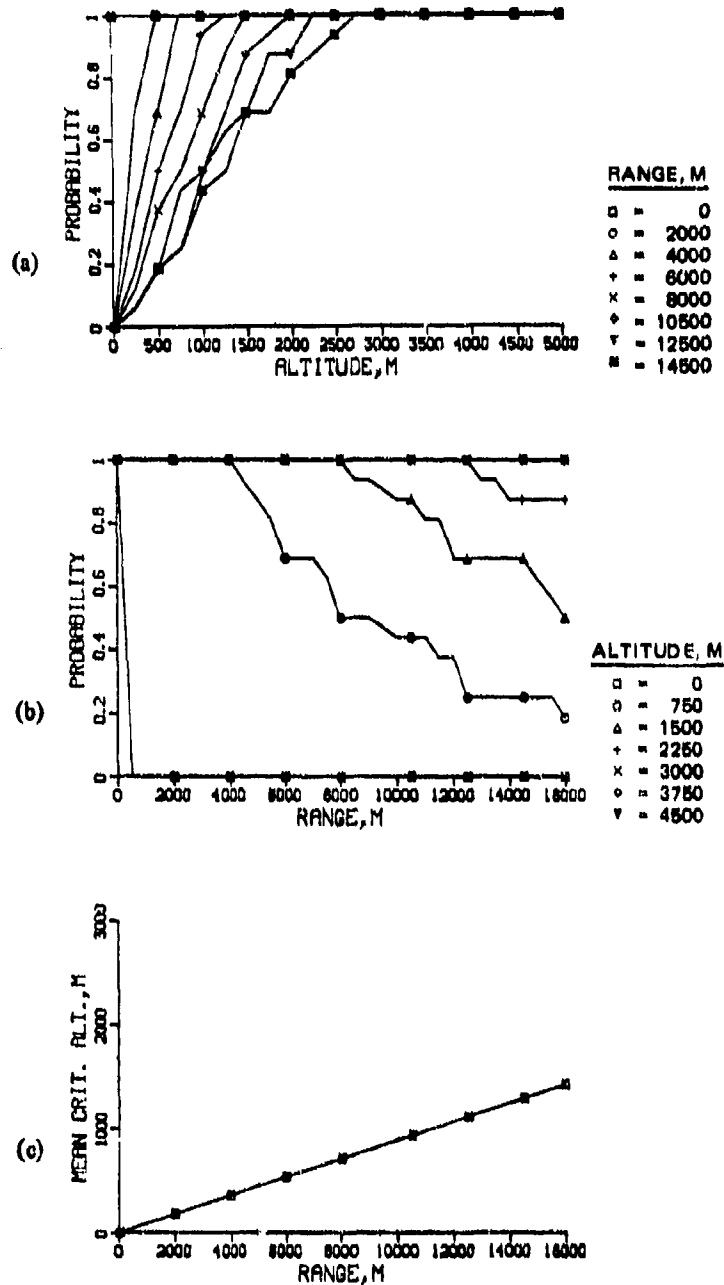


FIGURE 166. Site SSP 3: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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FIGURE 167. Site SSP 4, Ground Photograph.

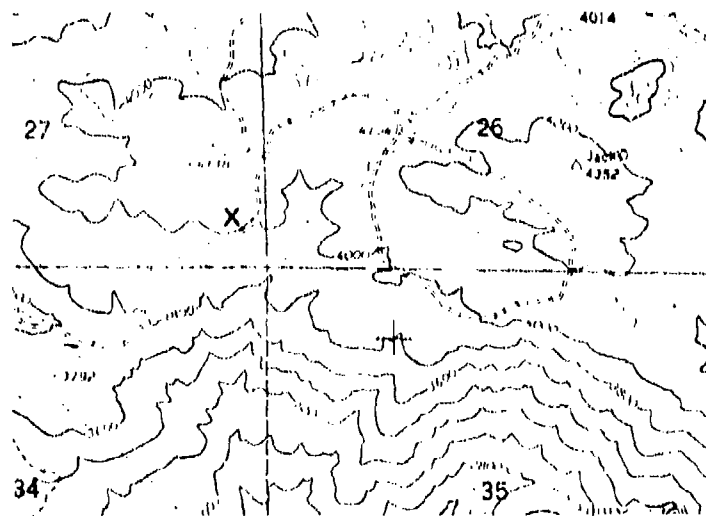


FIGURE 168. Site SSP 4, Topographic Map. Scale is 1:24,000; contour interval is 40 ft.

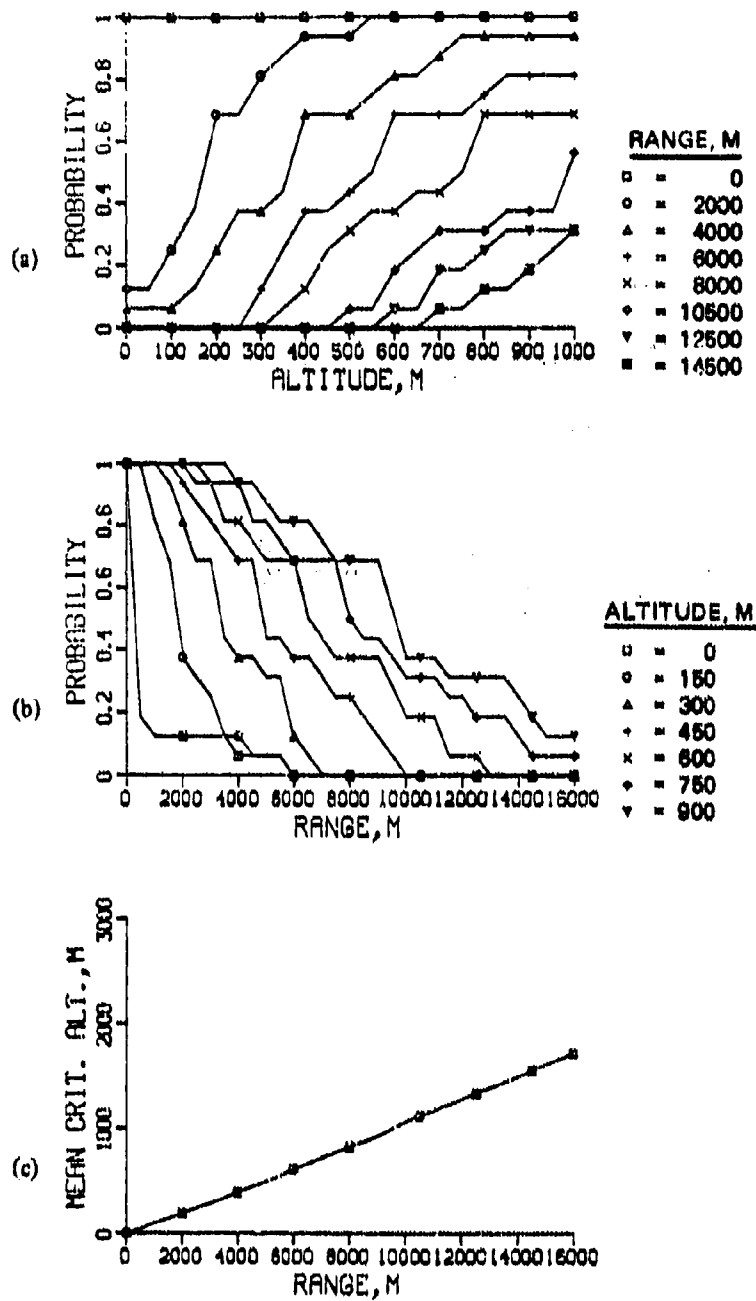


FIGURE 169. Site SSP 4: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

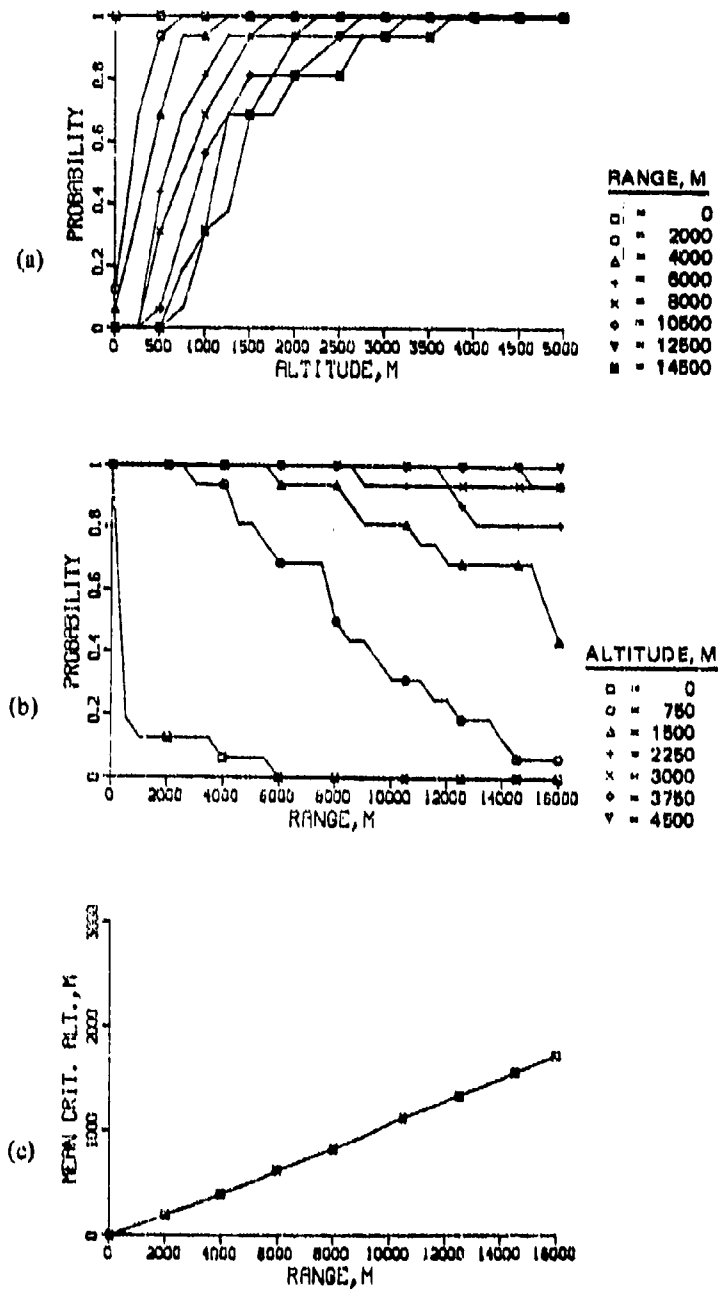


FIGURE 170. Site SSP 4: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

TERRAIN/VEGETATION TYPE G

Description: Desert, rough, with scattered bushes.

Data available: Aerial photographs, ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs (see Figures 171 through 192).

Number of sites surveyed: Five.

Site designations: MSP 1, MSP 3, MSP 4, RDM 2, WC 3.

Approximate number of LOS measurements: 100.



FIGURE 171. Aerial Photographs of Sites Used To Measure Terrain/Vegetation Type G, Showing Sites RDM 2 and MSP 1. (Site WC 3 may be seen in Figure 106, page 103.)

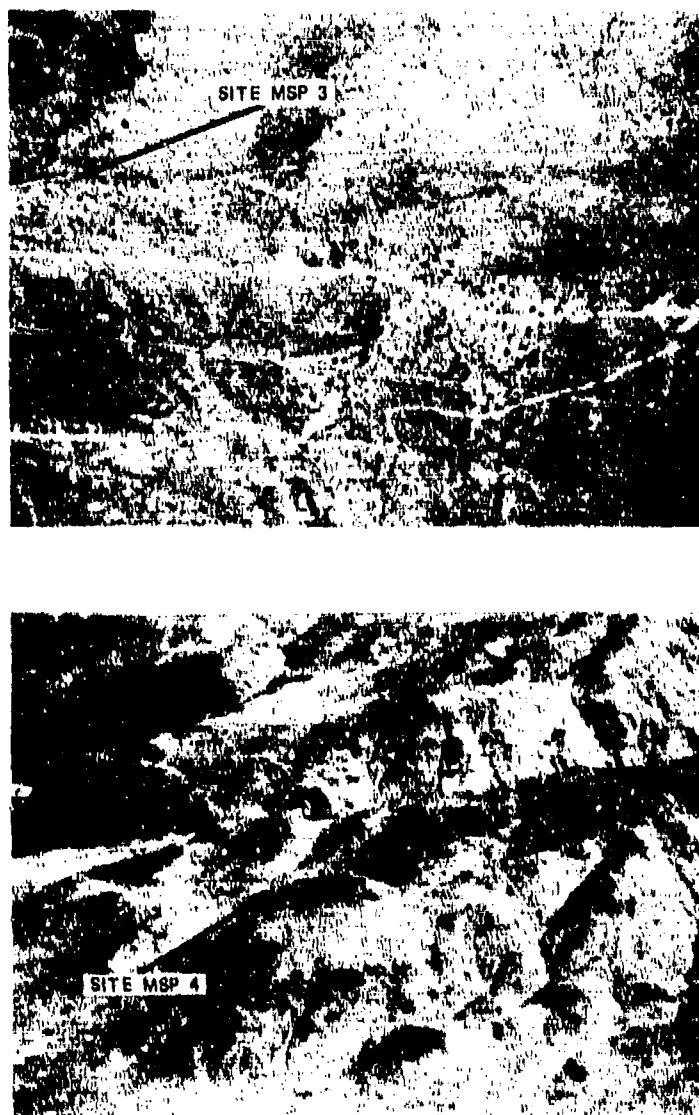


FIGURE 172. Aerial Photographs of Sites Used To Measure Terrain/Vegetation Type G, Showing Sites MSP 3 and MSP 4.

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FIGURE 173. Site MSP 1, Ground Photograph.

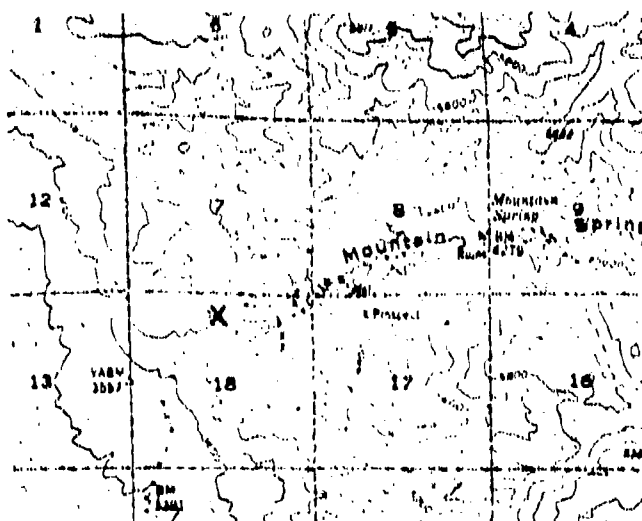


FIGURE 174. Site MSP 1, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

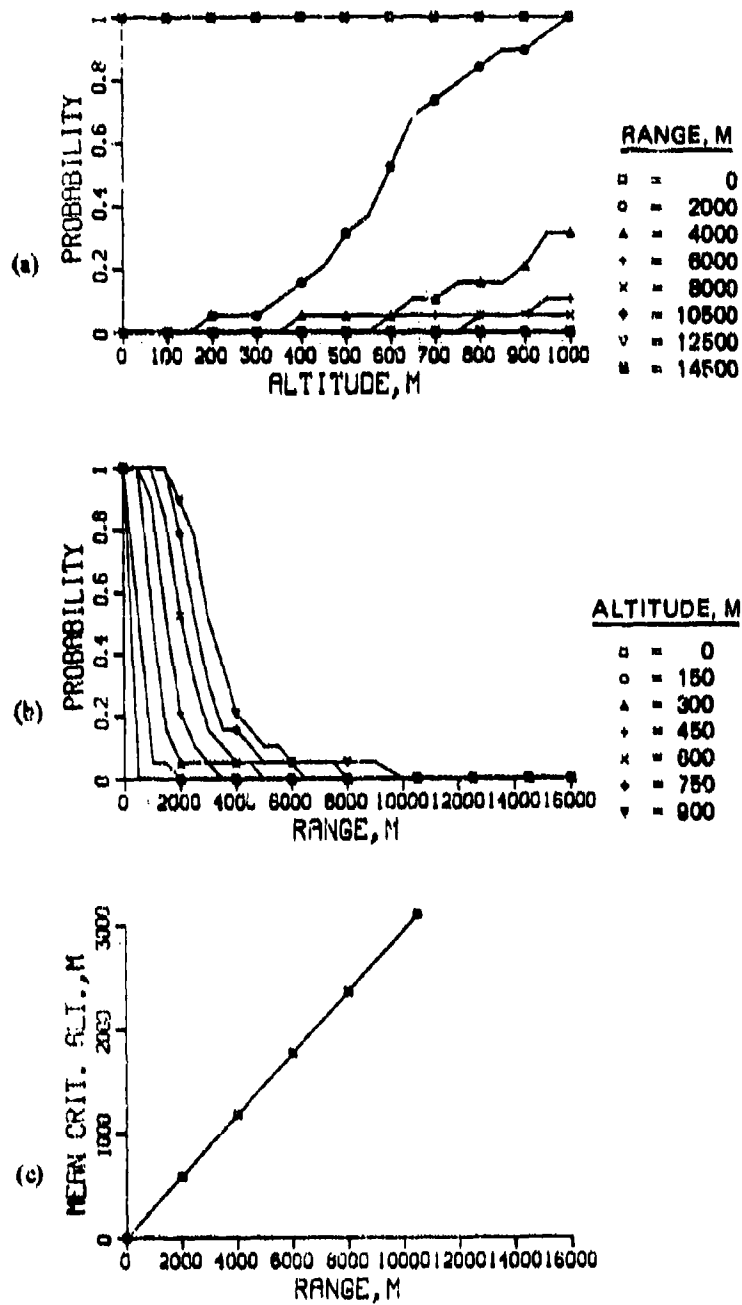


FIGURE 175. Site MSP 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

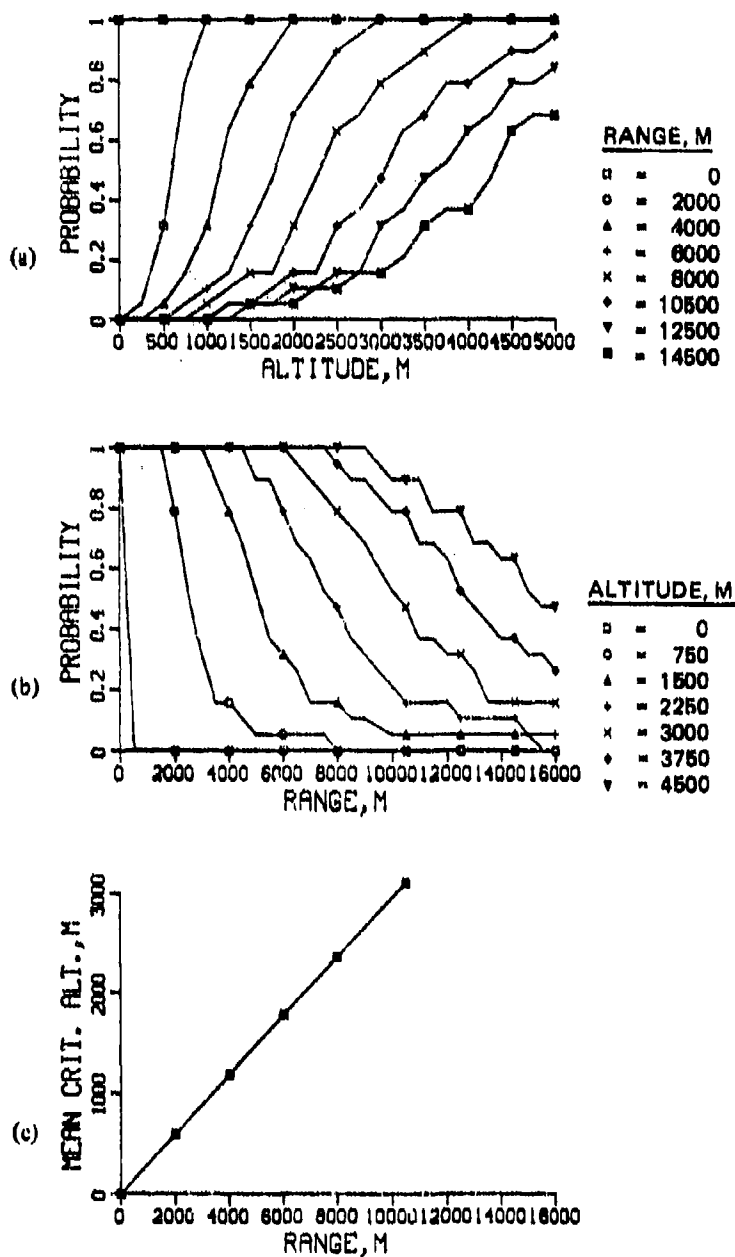


FIGURE 176. Site MSP 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

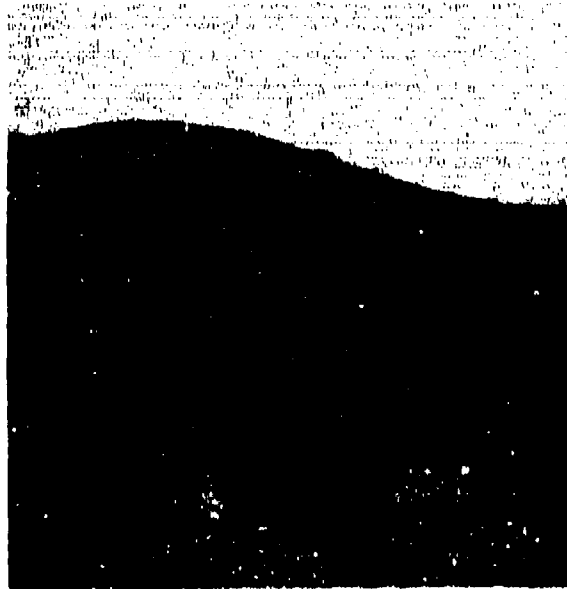


FIGURE 177. Site MSP 3, Ground Photograph.

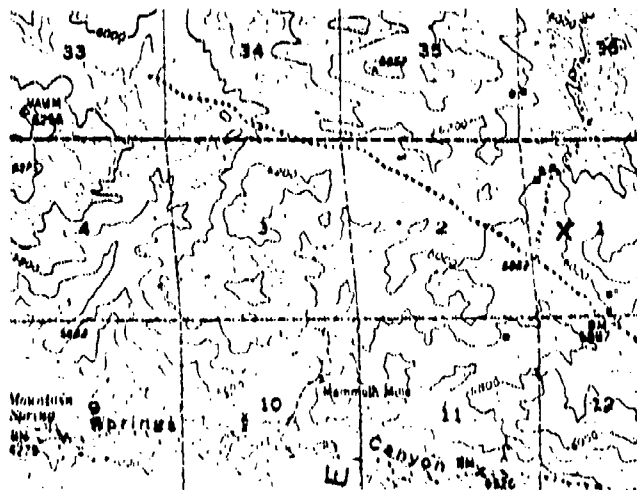


FIGURE 178. Site MSP 3, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

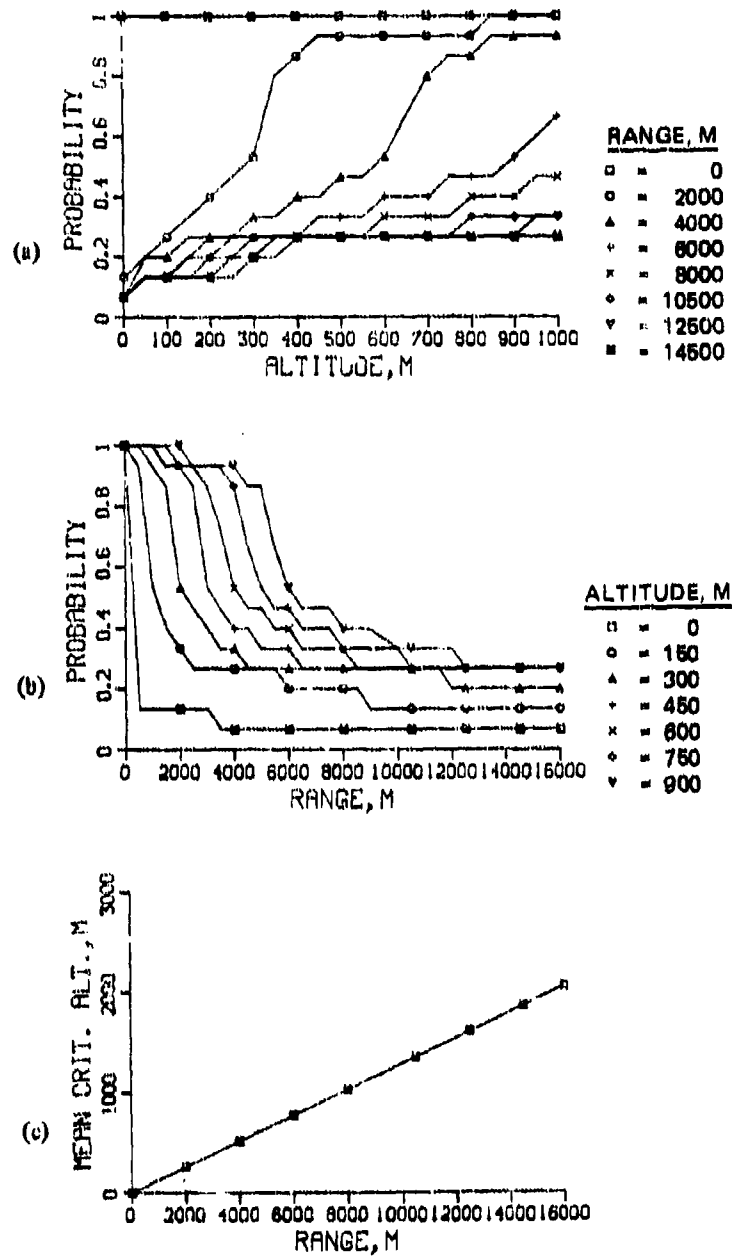


FIGURE 17^a. Site MSP 3: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

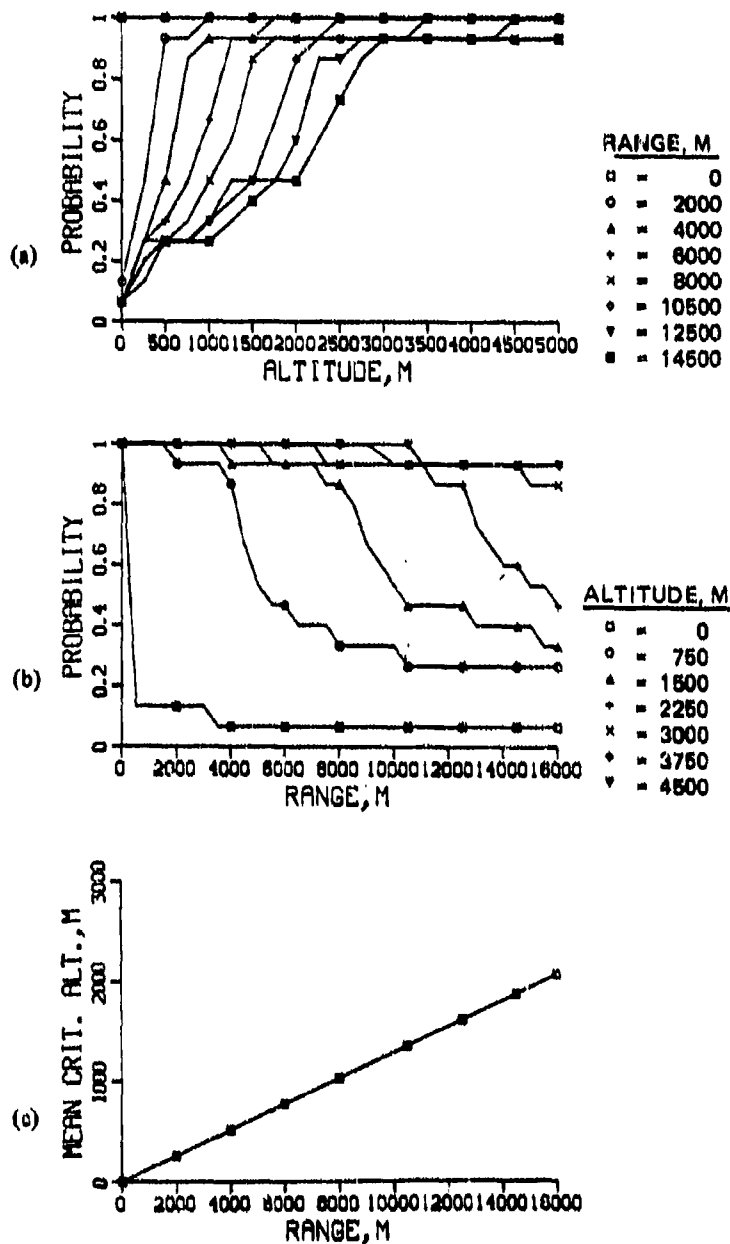


FIGURE 180. Site MSP 3: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

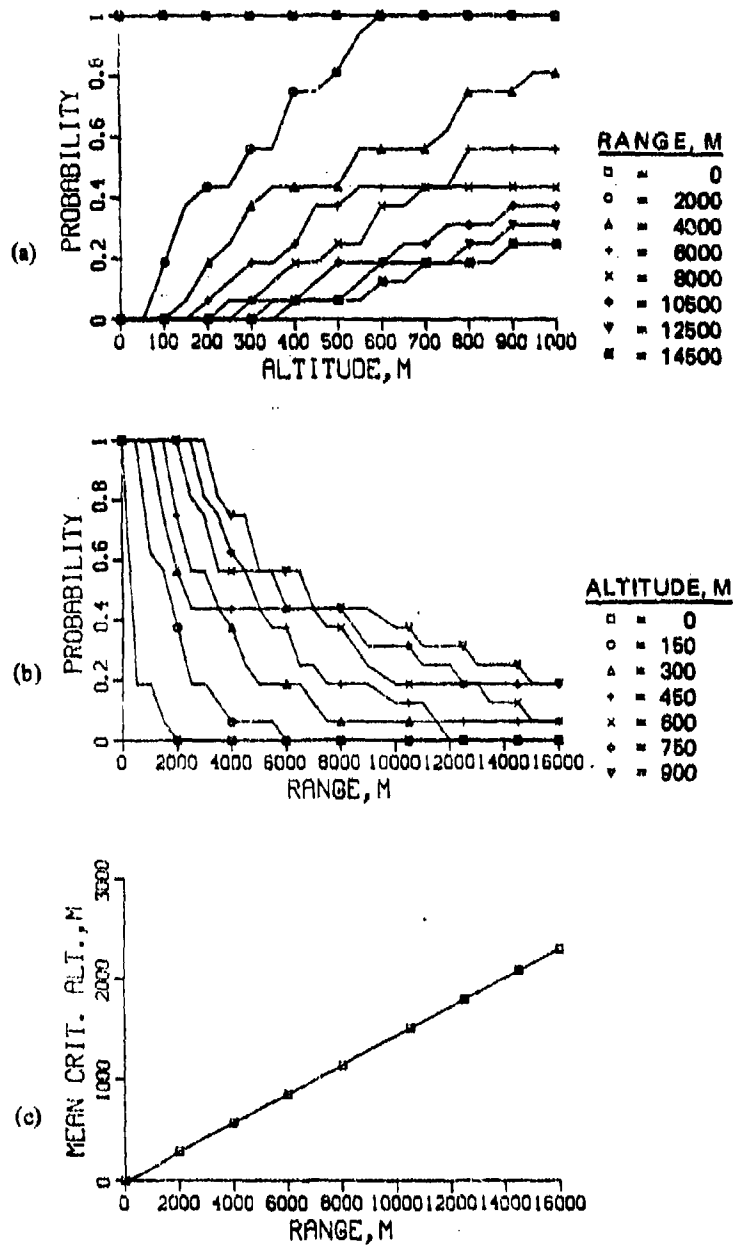


FIGURE 183. Site MSP 4: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

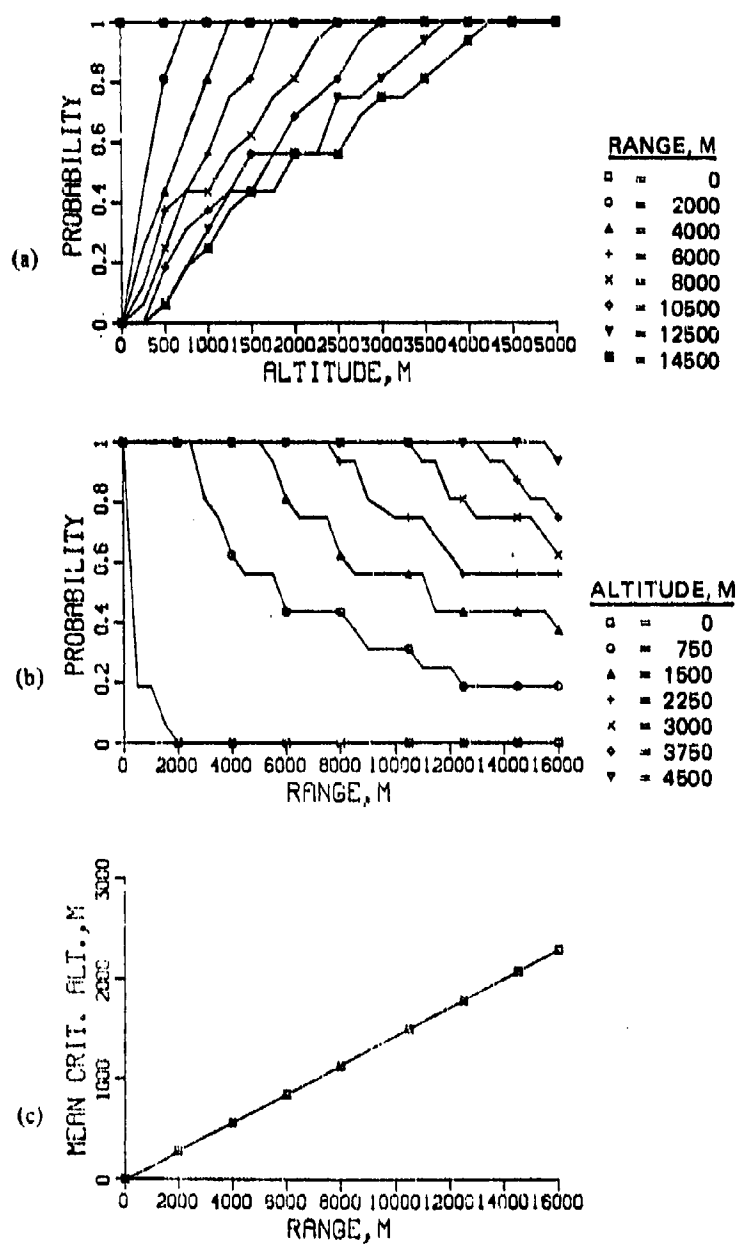


FIGURE 184. Site MSP 4: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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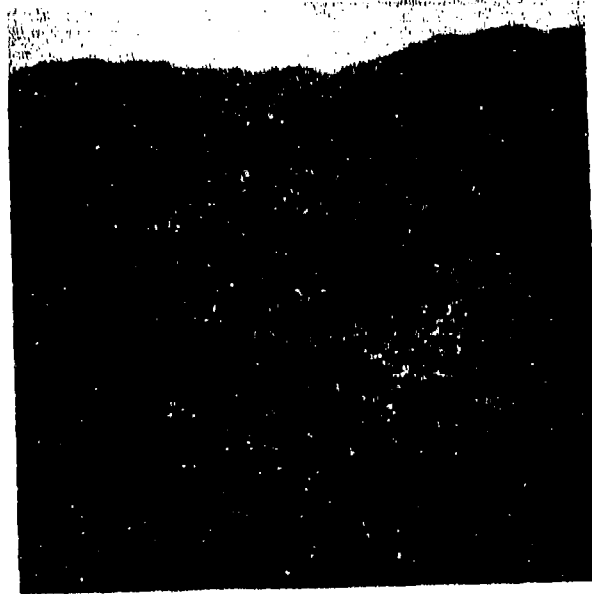


FIGURE 185. Site RDM 2, Ground Photograph.

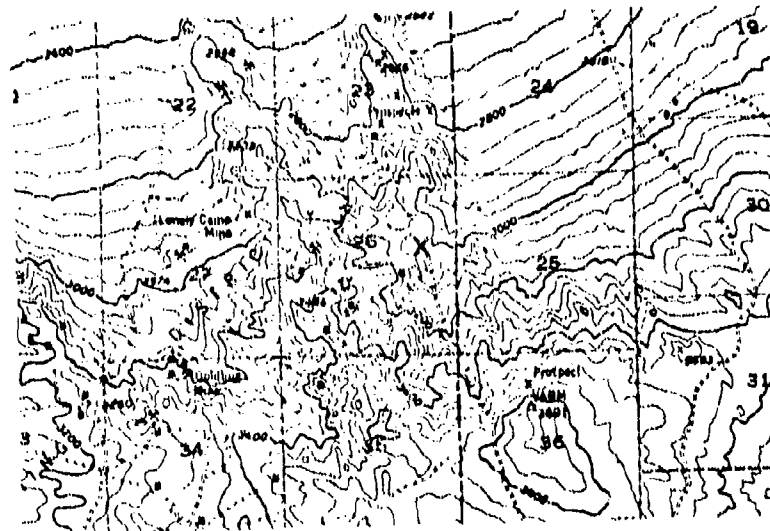


FIGURE 186. Site RDM 2, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

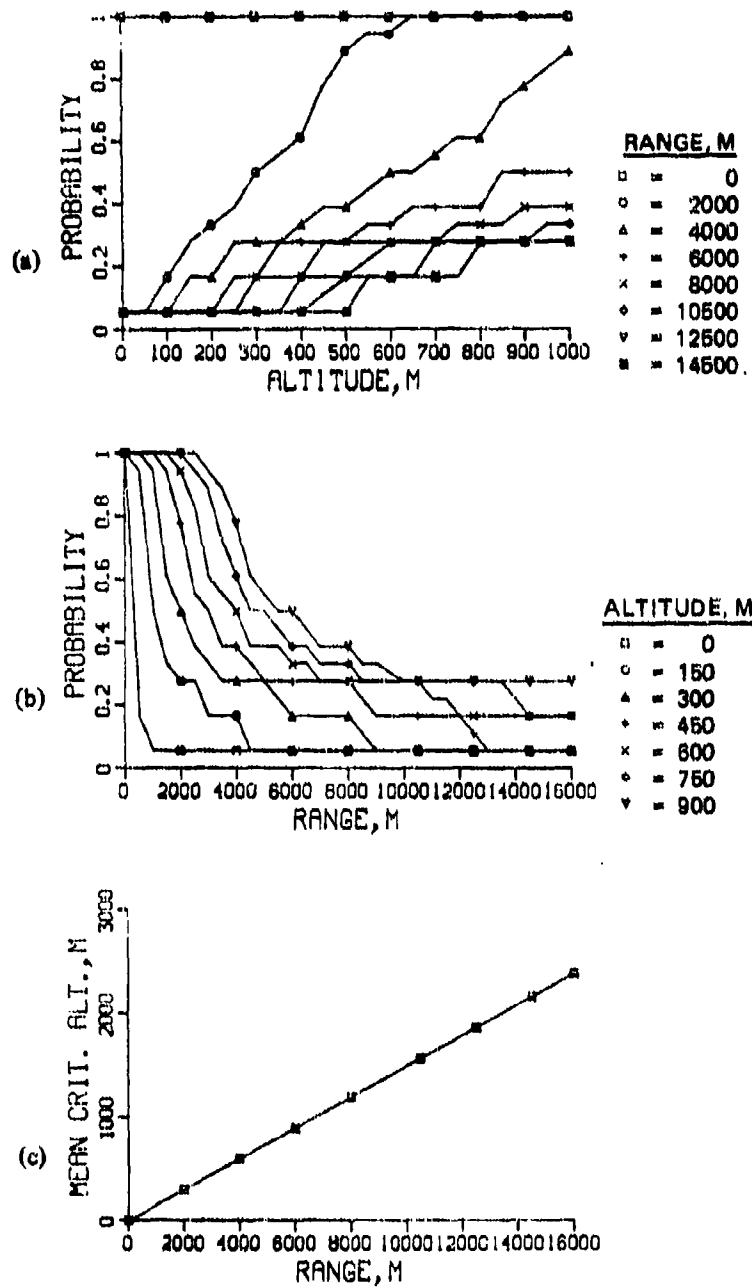


FIGURE 187. Site RDM 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

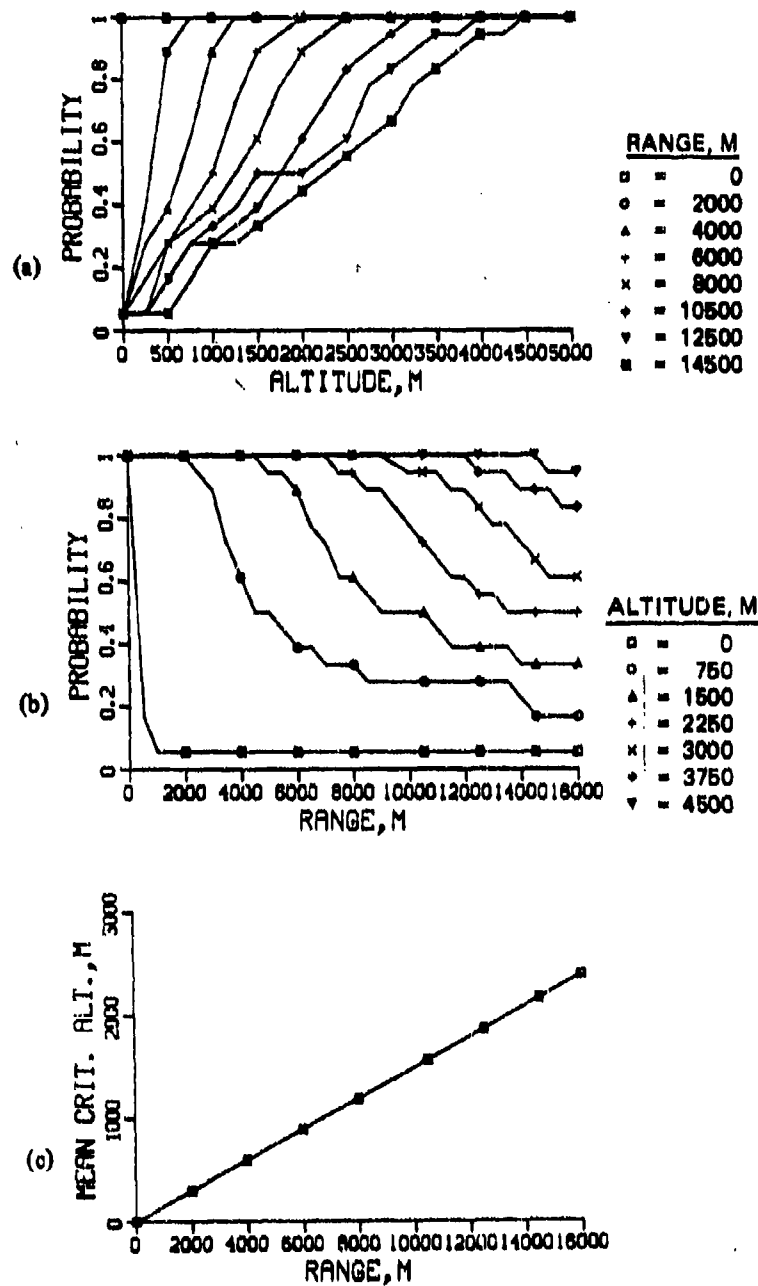


FIGURE 188. Site RDM 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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FIGURE 189. Site WC 3, Ground Photograph.

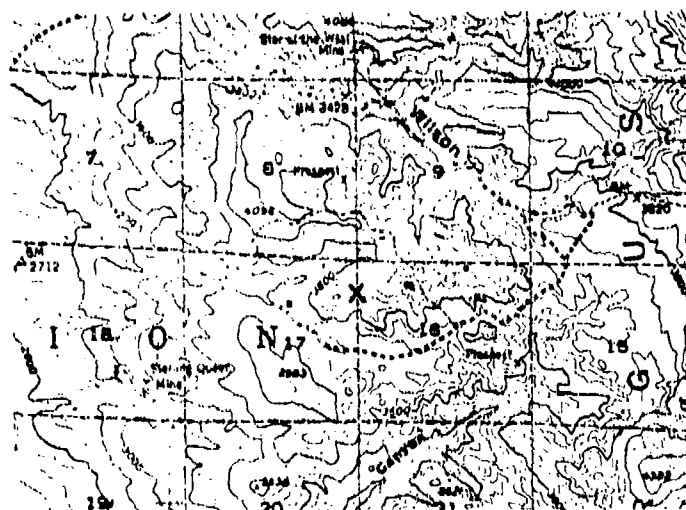


FIGURE 190. Site WC 3, Topographic Map. Scale is 1:62,500; contour interval is 40 ft.

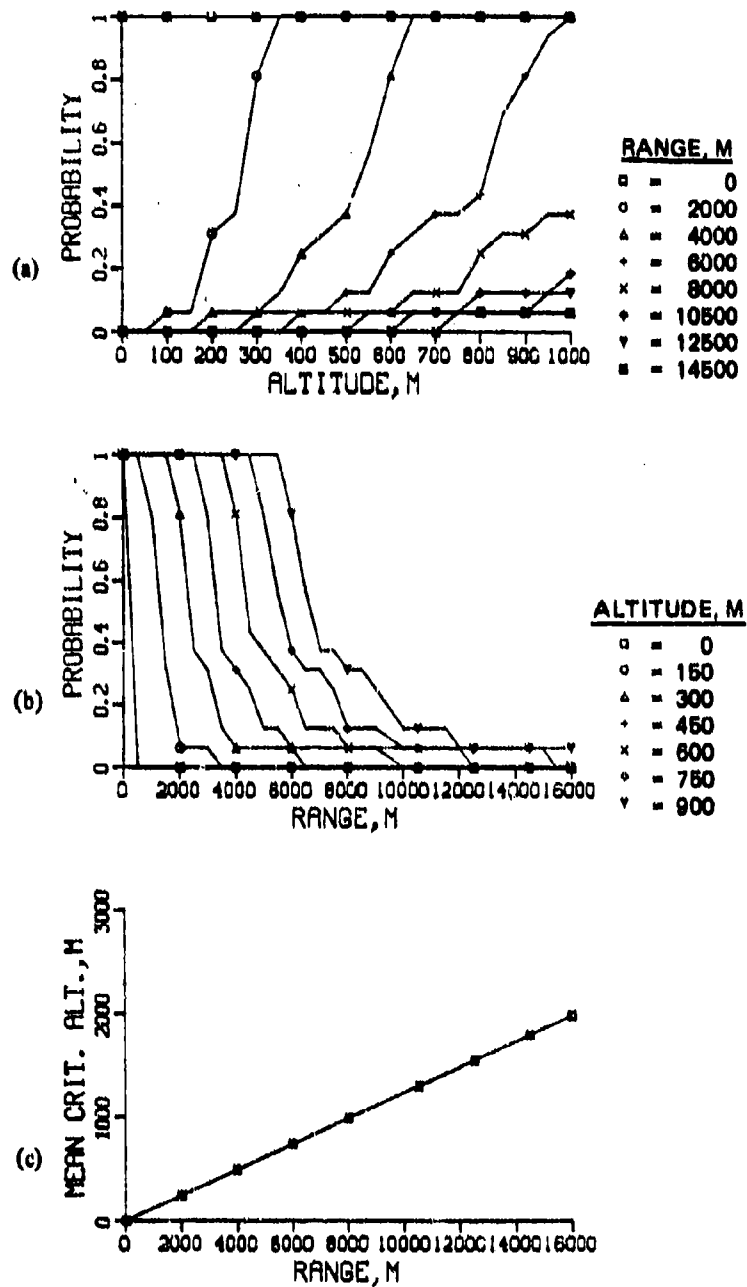


FIGURE 191. Site WC 3: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

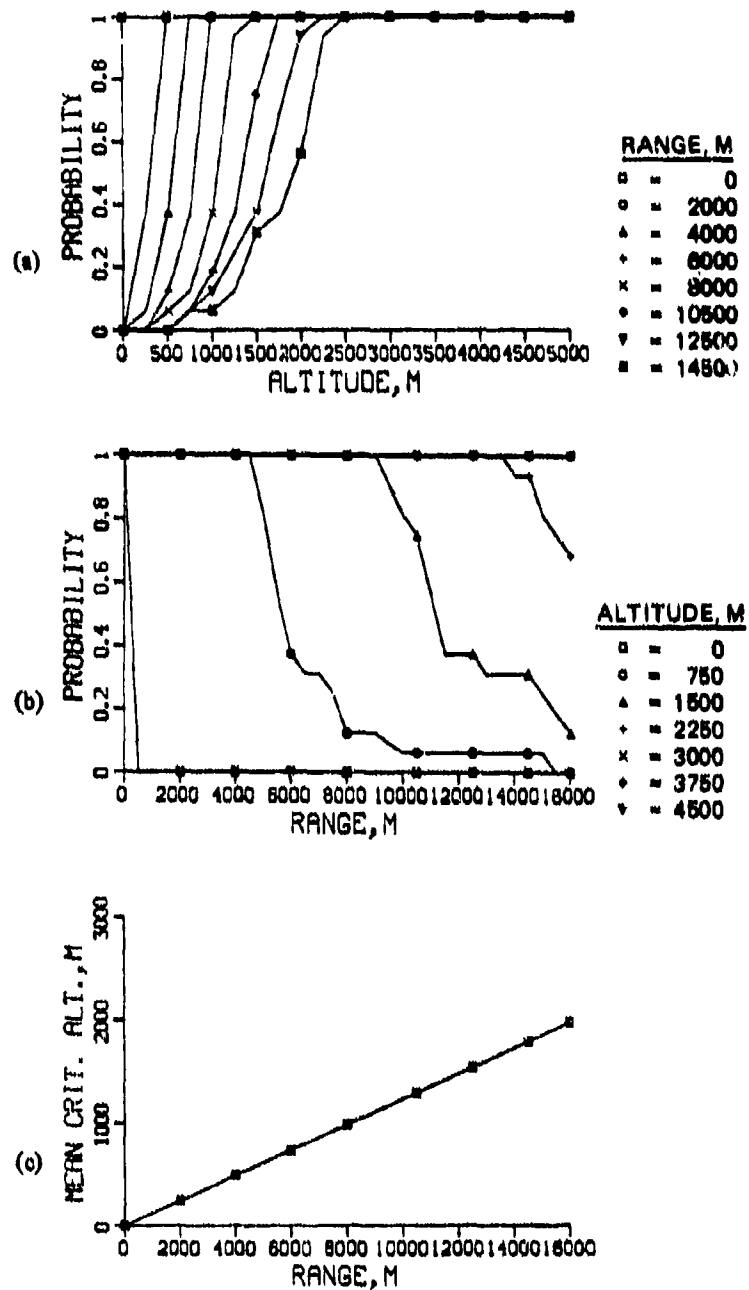


FIGURE 192. Site WC 3: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

TERRAIN/VEGETATION TYPE H

Description: Hills, sharply rolling, with thickly scattered trees.

Data available: Aerial photographs, ground photographs, topographic maps, probability of LOS graphs, mean critical altitude graphs (see Figures 193 through 201).

Number of sites surveyed: Two.

Site designations: SSP 1, SSP 2.

Approximate number of LOS measurements: 40.



FIGURE 193. Aerial Photograph of Sites Used To Measure Terrain/Vegetation Type H, Showing Sites SSP 1 and SSP 2.

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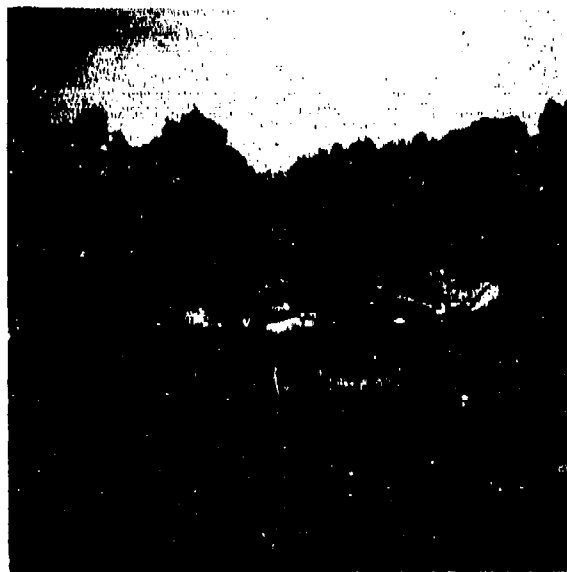


FIGURE 194. Site SSP 1, Ground Photograph.

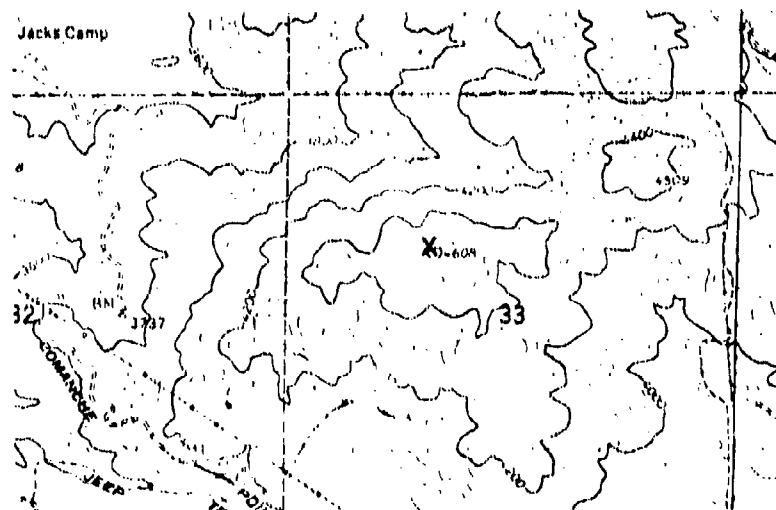


FIGURE 195. Site SSP 1, Topographic Map. Scale is 1:24,000; contour interval is 40 ft.

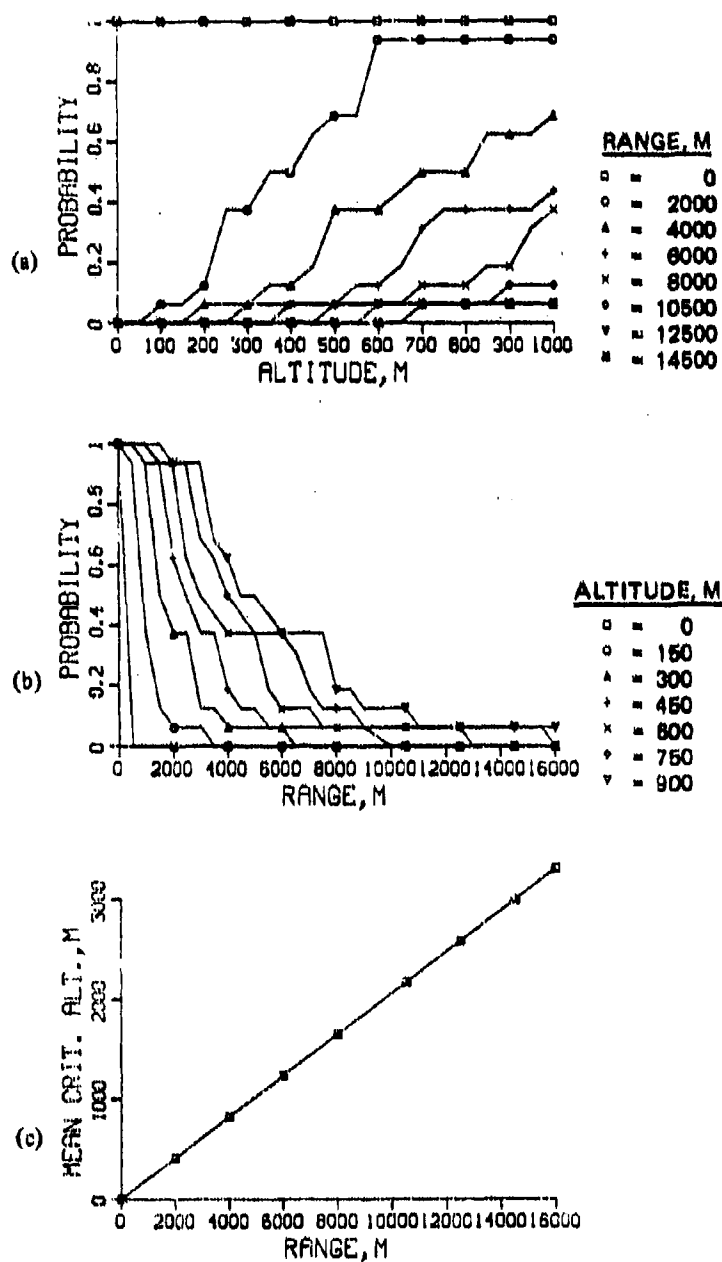


FIGURE 196. Site SSP 1: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

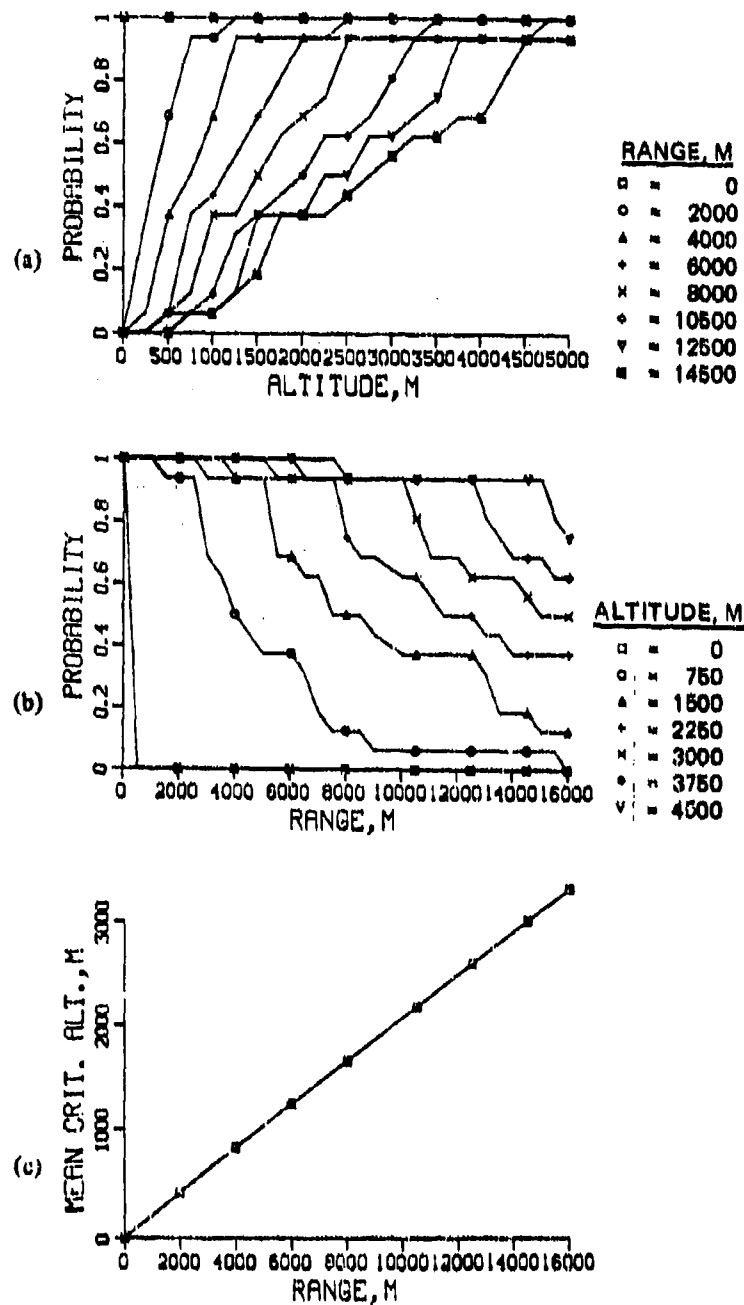


FIGURE 197. Site SSP 1: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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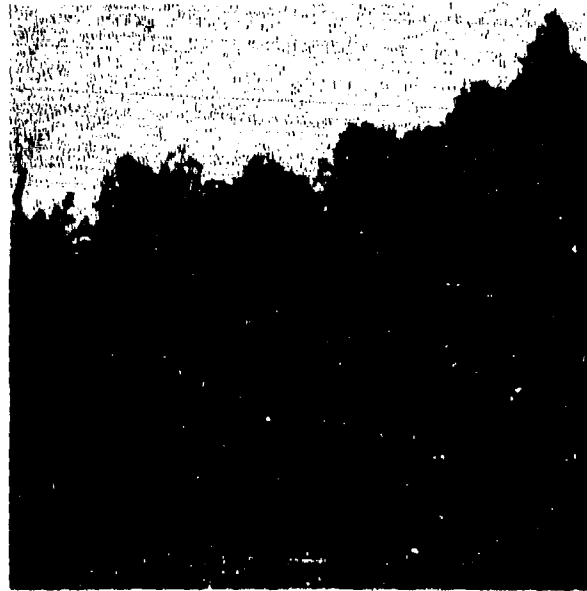


FIGURE 198. Site SSP 2, Ground Photograph.

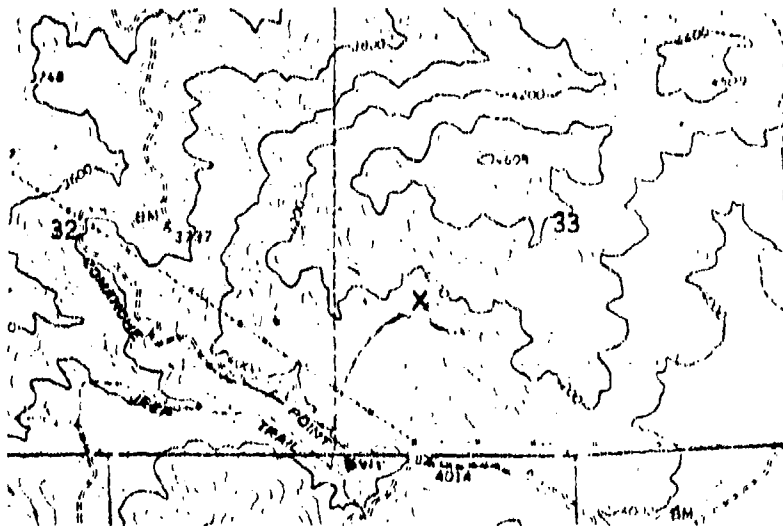


FIGURE 199. Site SSP 2, Topographic Map. Scale is 1:24,000; contour interval is 40 ft.

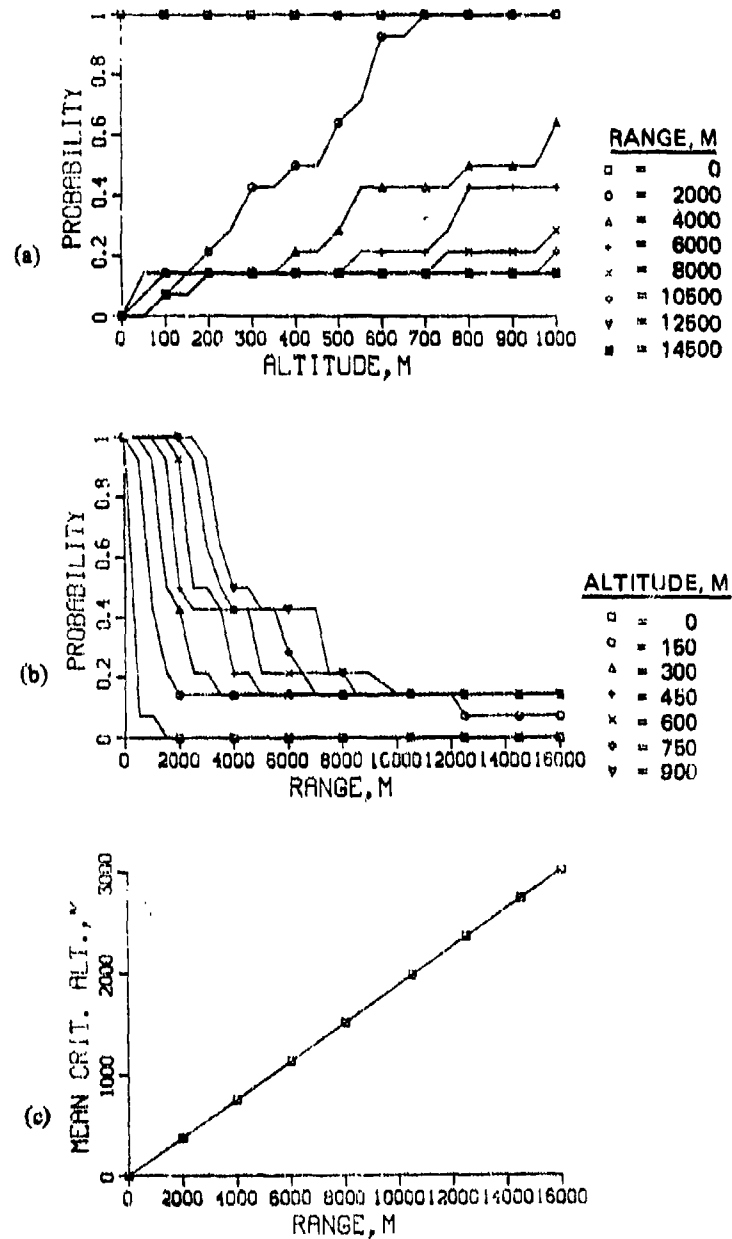


FIGURE 200. Site SSP 2: Probability of LOS as a Function of (a) Altitude up to 1000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

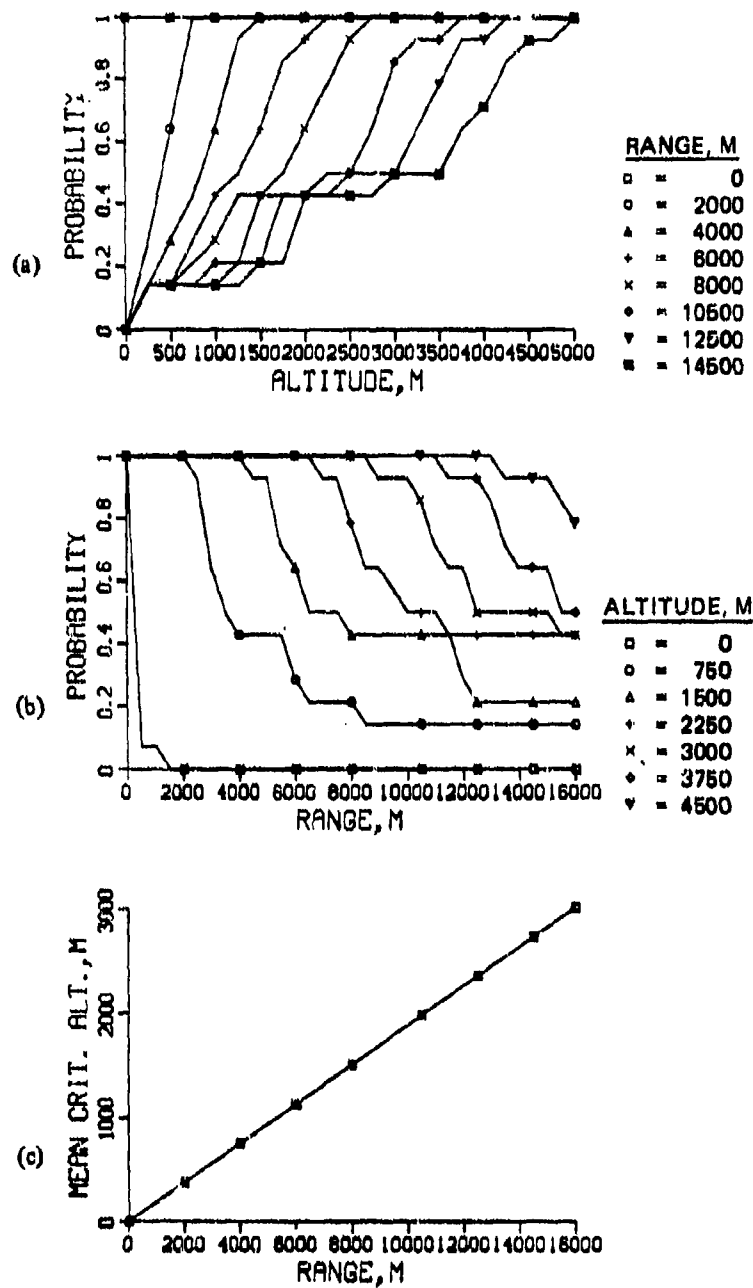


FIGURE 201. Site SSP 2: Probability of LOS as a Function of (a) Altitude up to 5000 m, and (b) Range; and (c) Mean Critical Altitude as a Function of Range.

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